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AMERICAN SOCIETY OF CIVIL ENGINEERS
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Paper No. 1190

THE VALUATION OF PUBLIC SERVICE CORPORATION PROPERTY.*

By Henry Earle Riggs, M. Am. Soc. C. E.

With Discussion by Messrs. F. Lavis, Charles H. Higgins, S. D. Newton, William V. Polleys, C. P. Howard, J. E. Willoughby, Henry C. Adams, Carl C. Witt, R. A. Thompson, Charles H. Ledlie, William G. Raymond, W. H. Williams, P. E. Green, E. Kuichling, Richard T. Dana, George T. Hammond, Leonard Metcalf, Charles Hansel, J. Martin Schreiber, Clinton S. Burns, Halbert P. Gillette, Arthur L. Adams, C. D. Purdon, A. Mordecai, W. B. Ruggles, and Henry Earle Riggs.

Introductory.

The industrial and economic development of the past two decades has opened many new lines of special work in the Profession of Engineering, none of which is more difficult and complicated or of greater ultimate value to the public at large than that of the appraisal or valuation of the property owned and operated by public service corporations; and none of the fields of engineering specialization requires greater care or calls for more skill, experience, integrity, or sound judgment.

The individual engineer, or commission of engineers, entering upon an appraisal of large magnitude, particularly one including properties of more than one company, will find conditions varying in every one, and each property presenting new, complex, and confusing elements of value to pass upon and determine.

Prior to 1900 there had been few calls on engineers for large appraisals, and the literature descriptive of engineering effort along

* Presented at the meeting of January 4th, 1911.

this line was practically nothing. Since 1900 many extensive appraisals have been undertaken by States, by railroad and banking corporations, and by cities; certain well-defined lines of practice have been developed; many differing opinions as to certain methods and principles have been brought out; and enough has been added to the printed literature to enable one to compare methods of work and to fix with reasonable certainty upon some as correct, and to discard others as improper.

There are so many complex factors entering into the problem of valuation, so many widely different plans have been presented, and there are so many thinking men who have opposed and do honestly and sincerely oppose any form of valuation, that a most thorough study of the subject should be made. It should be examined from all angles, and every possibility of danger from legislation regarding it should be weighed with utmost care.

The question of railroad valuation, involving as it does the largest industry of the nation, naturally takes first place in such a discussion, but so many of the general principles of railroad valuation are applicable to the appraisement of corporate property, so many arguments have been advanced by engineers and others, and so many judgments of the Courts have been rendered in connection with waterworks and gas-works valuations, that it is not desirable to limit this discussion wholly to the problem of railroad valuations.

The reasons for requiring that valuations be made may be broadly divided into two general classes:

First.—As a Matter of Public Interest.—The public, and particularly the investing public, requires valuations in order to guard against unworthy and dishonest corporation securities, to be assured that corporations are bearing their legitimate and proper share of the burden of taxation, and to furnish a proper basis for fixing equitable and just rates for the services rendered by the corporation.

Under this class would come all appraisals made for information to be used as a basis for legislation relative to:

(*a*) *Taxation of Corporations.*—Such were the valuations in Michigan and Wisconsin.

(*b*) *Rate Regulation.*—This was the reason which prompted the work in Minnesota and Nebraska.

(*c*) *Limitation of Capitalization.*—The regulation of issue of stocks and bonds was the purpose of the Texas valuation.

(*d*) *Fixing a Price for Sale.*—Many of the water-works and electric light valuations were made in order to determine a fair price to be paid for the property at the expiration of the franchise.

(*e*) *The General Information of the Public.*—To be used in connection with the fixing of terms for franchise renewals, etc., etc.

Second.—As a Matter of Corporation Necessity or Expediency.—Valuations are made in order to guide large investors, to secure a safe and up-to-date basis on which to negotiate a sale, a purchase, or a reorganization of the property, or a consolidation with other like properties, and to secure justice to honestly administered corporations.

The great majority of appraisals under this head have been in accordance with some other methods than those adopted in the State valuations. It is not intended in this paper to engage in any argument as to the various purposes of appraisals, or even to urge the necessity or desirability of a general appraisal of properties. An absolutely accurate and correct statement of the cost of reproduction of all the physical properties of the railroads of the country, a correct statement of the actual capital needed to reproduce these properties as they exist, and, along with this, a statement of the actual physical depreciation, would be a document of vital interest.

This paper is confined to a discussion of the methods which should be used in arriving at a correct figure of cost of reproduction and depreciation—it does not take up questions involving the propriety of those figures when reached. The propriety or legality of using such figures as a basis for an assessed valuation, as a basis for rate-making (rate-making being an art in itself involving complications as great as those encountered in valuation), or any arguments as to the justice or injustice of legislation restricting issues of stocks or bonds, will be conceded no place in this paper. It is assumed that all these questions would have been taken up and a satisfactory answer reached before a valuation could have been ordered.

The different elements of value in property, the relations of this property to the public, the method of determining the worth of these elements of value which have been adopted in the past by men engaged on valuation work, a comparison of these methods, a discussion of the objections that have been made to them, and a presentation, not only

of the writer's views as to proper methods, but those in which he disagrees with usages adopted by others—these define the scope of this paper.

No matter what particular end is to be served by a valuation, the commission engaged upon it will be asked to furnish a fair value, perhaps with reasonable limitations in the instructions, perhaps with a general and indefinite instruction to find the value. They will encounter, among other difficulties:

First.—The fact that human machines are not exact duplicates, and that allowance must be made for a large measure of error, on account of the personal equation of the men engaged on the work, as individual errors of judgment are frequent on any work of magnitude. This personal element must be corrected by uniformity of method, by constant checking, and, as far as possible, by subordination of personality to system.

Second.—The fact that human selfishness is a dominant quality—the railroad manager who opposes methods which he believes will increase values in an appraisal for taxation, or who, on the other hand, uses every possible argument to increase values if the work be as a basis for rate-making or for restriction of bond issues, or the State official who is desirous of using original cost on a valuation to be used for rate-making in order to keep the valuation down to a minimum, and the politician who depends on an unenlightened public opinion to create sufficient outcry to influence the work to his advantage—are all actuated by a perfectly human wish to attain ends which seem to them desirable, and are but typical of men who will endeavor to influence every appraisal.

In view of these considerations, it is a question whether results are not frequently affected by the knowledge of their intended use, and whether a system which will entirely remove such causes of error can be applied to the work.

If an engineer, or a commission of engineers, is directed to examine a certain property and report the true cost of reproduction, depreciation, or present value, taking into account all facts connected therewith, the final figures should not differ, whether the report is to be used as a basis for reorganization, sale to another corporation, or is to be used by a State legislature as a basis for formulating a rate bill, or as a basis for a value for taxation. The result secured is a

necessary preliminary on which depends the accuracy, fairness, and justice of the other work which is to follow. This is an engineering work, a statement of certain physical property, the estimated cost of reproducing it new, less the estimated depreciation, and, beyond the differences due to personal judgment, these figures may not vary.

The word "value" is in common use, and yet, in the minds of many people, its exact meaning is vague. It is true that the "value" of a property is an unstable figure, subject to fluctuations due to natural or artificial causes, and that a material change in value may occur suddenly, but the "value" of any given property on any given date is, or should be, from an engineering standpoint, a definite sum which may not be varied or changed to suit the whim or will of the people for whom the work is done.

In all the subsequent discussion of values and methods of obtaining values, it is assumed that, unless specifically limited to a determination of cost of reproduction and depreciation, a valuation commission should be governed by the following rules:

1.—No account may be taken of the purpose for which the resultant figure of value is to be used; and the result should not vary, no matter what that purpose may be.

2.—The resultant figure should be the honest judgment of the men composing the commission, as to the actual cost of reproduction, present physical value, or "fair value," and should be ascertained by a systematic and scientific method which takes into account all the facts concerning the property, its physical value, its strategic location, its operating revenues and expenses, and its franchises, rights, competition, opposition, and all other tangible or intangible elements which would affect values. The method of valuation should be such as to minimize or entirely eliminate all differences due to errors of personal judgment.

3.—All properties being appraised are considered as operating properties. One which is dead, inert, and not in use, cannot be considered as coming under such a discussion as this, and such properties are not treated in this paper. The term "going concern" is not used in connection with the physical property, any element of value implied by the term, over and above the "overhead charges," being treated as an intangible or non-physical element of value.

In stating this position, the writer is aware that it is a difficult matter indeed to get away from the fact that some specific purpose—taxation, for example—is the definite end in view in every valuation, and that, instinctively, men engaged on the appraisal will find themselves modifying their figures to meet some real or fancied condition which they conceive might arise, or to prevent some injustice which they believe might be done. Every subordinate employee needs to be watched, every man in charge must watch himself, or he will find himself unwittingly, almost instinctively, coloring his results by some old prejudice of his early years of employment, or some loyalty to his own ideas of governmental or economic policy. The writer has noted this in every appraisal on which he has been engaged, and calls particular attention to it as the first difficulty which must be overcome in the organization of the force for a large appraisal.

In the following pages all complications which might arise from the purpose of the appraisement are considered as eliminated, and the possibility of erroneous conclusions being reached by reason of the personal factor (while recognized as being ever present) will not be specially emphasized.

The Relation of Public Service, or Quasi-Public Corporations, to the People.

In reference to questions of value, the engineering commission must hear, consider, and reconcile arguments advanced by adverse and often hostile interests. On the one side stand the corporations, with large financial interests involved, often with an excessive amount of stock and bonds issued on the property, the existence of which issues the corporation wishes to justify, and, whether properly capitalized or not, the management being imbued with the perfectly human desire to defend corporate interests from attack of any kind; on the other side is public opinion, often unreasonable, often misinformed, and frequently prejudiced.

It appears necessary, therefore, to consider briefly the relation which these interests bear to one another, to study the causes which have led to mutual misunderstandings, and to note the proper relations which should, if possible, be established and maintained between the people and those corporations organized to perform certain of the functions of the State.

A public service or quasi-public corporation is a corporation which is operating under the terms of rights, grants, or franchises given by the public, either to this particular corporation direct or granted by statute to a class of corporations.

The property of the corporation is used to render certain services to the public, with the expectation of financial gain.

It is not material whether the grant be a franchise permitting a water-works company to use the streets and alleys of a city for its mains, and the service be the pumping of water for domestic service and fire protection, or whether the grant be the statutory rights of corporate existence and eminent domain, and the service rendered be the transportation of freight and passengers; the general principle is the same; the company has secured from the people certain rights which enable it to do business, and the people are directly benefited by the services rendered by the company. The increased comfort of living makes for the growth of the city; the increased transportation facilities build and develop the country traversed by the railroad; and this growth and development, not only operate to the advantage of the people, but also to that of the company in the way of increased business and increased revenues.

The capital required to build and develop these properties was furnished in the hope of, and with the expectation of, a proper financial reward. It has frequently happened that such properties have been built years in advance of sufficient development to support the enterprise, built, in fact, without expectation of immediate returns, and long periods of time have often elapsed before any profit has been secured.

It has also frequently happened that corporations have been aided to a very large extent by public funds, by the voting of aid bonds, by the donation of large tracts of land, by payment for certain service at such rates as would largely relieve the company from loss in operation, by the remission of taxes, or by the direct donation of funds.

The company is clearly entitled to earn a reasonable profit on the actual capital invested, in addition to the legitimate cost of operation, payment of taxes, and sinking funds to cover depreciation and obsolescence.

The public is clearly entitled to good service at the lowest rates that will permit the company to earn its reasonable profit and expenses. Increases in tonnage, population, and consequent net earn-

ings of the corporation should entitle the public to a benefit in reduced charges for service, when the increased earning is of a permanent character.

The general tendency of the Courts has been to treat a franchise as a contract, and to be governed closely by the language and evident intent of the makers, but to safeguard the rights of the public to the fullest extent consistent with justice.

A franchise requires specific performance of specific acts. Nothing will be assumed or implied. The Courts recognize that the investors are entitled to reasonable returns, and that the public is entitled to fair rates.

In the case of Los Angeles Water Company *vs.* City of Los Angeles (103 U. S., 711), the United States Courts held that at the expiration of a 30-year franchise, which provided that the city was to pay for the value of all improvements, when the city failed to agree upon, tender, or pay such value, so long as the company complied with the terms of the contract, and until the city terminated it by making or tendering payment, the passage of an ordinance by the city fixing rates was void.

In the case of Weatherly *vs.* Capital City Water Company (Ala. 22 So., 140), the Alabama Courts held that the acceptance of a franchise involved a grave responsibility, and that the company could not stop furnishing water and fire protection, even if the work was done at a loss.

In the case of Myer *vs.* Brown (65 Cal., 589), the Court said:

"It is well occasionally to recall the fact that there is no more reason to permit a municipal government to repudiate its obligations entered into for value, than to permit an individual to do so. Good faith and fair dealing should be exacted of one equally with the other."

Judge Brewer, in the Kansas City Water-Works case (62 Fed. Rep., 853), said:

"All contracts involving property rights and obligations, between municipalities and individuals, must be presumed to be based upon and to recognize the ordinary laws of business transactions."

In 1903 the Maine Supreme Court issued a set of instructions to appraisers appointed to fix values of certain properties. The Court set forth its views as follows:

"Summarized, these elemental principles are, the right of the company to derive a fair income based upon the fair value of the property

at the time it is being used for the public, taking into account the cost of maintenance and depreciation and the current operating expenses, and the right of the public to demand that the rates shall be no higher than the services are worth to them, not in the aggregate, but as individuals."

The Supreme Court of the United States has again and again given its views, which may be summarized as follows:

"It cannot be said that a corporation is entitled, as of right, without reference to the interests of the public, to realize a given per cent. upon its capital stock. When a question arises whether the legislature has exceeded its constitutional powers in prescribing rates to be charged by a corporation controlling a public highway, stockholders are not the only persons whose rights and interests are to be considered. The rights of the public are not to be ignored.

* * * * * * *

"The public cannot properly be subjected to unreasonable rates in order simply that stockholders may earn dividends. The legislature has the authority in every case, where its power has not been restrained by contract, to proceed upon the ground that the public may not rightfully be required to submit to unreasonable exactions for the use of a public highway established and maintained under legislative authority." (164 U. S., 578.)

"It is not to be inferred that the power of limitation or regulation is itself without limit. This power to regulate is not a power to destroy, and limitation is not the equivalent of confiscation. Under pretense of regulating fares and freights the State cannot require a railroad corporation to carry persons or property without reward, neither can it do that which in law amounts to the taking of private property for public use without just compensation. * * *" (116 U. S., 307.)

In the case of Smyth *vs.* Ames (169 U. S., 466), the Court said:

"If a railroad corporation has bonded its property for an amount that exceeds its fair value, or if its capitalization is largely fictitious, it may not impose upon the public the burden of such increased rates as may be required for the purpose of realizing profits upon such excessive valuation or fictitious capitalizations; and the apparent value of the property and franchises used by the corporations, as represented by its stocks, bonds and obligations, is not alone to be considered when determining the rates that may reasonably be charged. * * *

"We hold, however, that the basis of all calculations as to the reasonableness of rates to be charged by a corporation maintaining a highway under legislative sanction must be the fair value of the property being used by it for the convenience of the public.

* * * * * * *

"What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public highway than the services rendered by it are reasonably worth."

The relations between the corporations and the public that they serve have been clearly defined by the Courts, as the foregoing quotations show.

That the mutual relations existing between the management of the corporations and the public are far from what they should be, there can be no doubt. On the one hand, the great mass of the voting public is uninformed as to actual revenues, disbursements, and operations of the corporations, as to whether their income is unreasonably large, or whether they are struggling to exist. The sums of money involved in the dealings of the corporations are so stupendous in comparison with the amounts used in an ordinary private business—even in one of considerable magnitude—that the majority of the public cannot comprehend them. The published statistics are in such form that only the careful student of affairs can understand or analyze them, and but few of the public officials who receive them are able to read the reports of the properties and comprehend them. As a consequence, the corporation, as a political issue, has been the subject of jest, gibe, and cartoon; there has not been an intelligent public discussion of available reports and statistics, and it may be said that, generally, the mass of the public has come to class all corporations as grasping, overbearing, and unjust, and to consider them all as exceedingly prosperous. This has been taken advantage of by politicians for their own selfish ends, and has led to sundry legislation, some of which has been unreasonable and unjust to the corporations, and much of which is aimed at real abuses that never ought to have existed.

The reasonableness of a rate depends, not alone on the amount of capital invested, but on the volume of traffic, the density of population, the actual cost of service, and many other elements. Rate legislation has been attempted without full investigation. Acts have been passed compelling the establishment of stations and terminals, the improvement of roadway and structures, the purchase of new equipment, the installation of safety appliances and block signals, and many other requirements have been made, some (but by no means all) of

which are unreasonable and burdensome. Nearly one-half the States of the Union have by law required a 2-cent, or 2½-cent, passenger fare, regardless of density of population, amount of traffic, or other considerations which might render such rates unreasonable. The regulation of the carriers, by legislature, by railroad commissions, by State officials, and by Courts, the addition of burdens of expense, and the cutting off of revenue, all give considerable ground for the opposition of the carriers to anything that looks like hostile legislation, and compels the student of affairs to admit that there is justice in the claim of the managements, that there is grave danger, not only of seriously crippling many roads, but of so impairing the credit of the railroads as a class that it will be increasingly difficult to secure capital to provide for the necessary extensions and development of the transportation facilities of the country.

On the other hand, perfect frankness compels the admission that the state of public opinion which compelled the passage of these laws has been caused largely by the corporation officials themselves. There is probably no more loyal body of men in America to-day than the officials and employees of railroads. Their loyalty, however, is all to "our company." They enter its service as boys or young men; they grow up to the full strength of manhood working for its good; they take little or no part in public affairs; they have no time for the study of public questions. Their friends are almost exclusively among their own associates in the service of the road, and their development is along the lines of their own special work in the service. As a body of honest, honorable, and worthy men, absolutely loyal to their employers, they have few equals; but it is doubtful if any equal number of men, of equal intelligence, have as limited a knowledge of the fundamental truths of government, or knowledge so colored by bias. It is also doubtful whether any equal number of men have in their ranks so few who bear an active part in the duties and activities of citizenship, or who exercise large influence on their neighbors.

While the foregoing statement is believed to be absolutely true, it will not do to pass over the notable exceptions. Such men as James J. Hill, F. Am. Soc. C. E., M. E. Ingalls, and others of the higher officials, who have taken an active part in public affairs, have had commanding influence. Theirs has been the sound policy, as the property in their hands has not suffered. The short-sighted

policy which, in December, 1909, induced the management of one road to compel all its employees holding municipal offices to resign, is bound to react and create hostile feeling on the part of the public.

The entire trend of a training in railway service is to fill a man with prejudice against all things that undertake to regulate or control the corporations, and often goes so far as to enable him to do, willingly and as a matter of right, things which with a broader view of the interest of the whole community he would not agree with at all. The result of this intensive training is that the railway service has in it thousands of men who become impatient with any effort to regulate or control; who permit their irritation to show; and who, by their own attitude, create unnecessary hostility. F. A. Delano, M. Am. Soc. C. E., President of the Wabash, in an address* at Hannibal, Mo., on March 25th, 1909, said:

"In ordinary manufacturing or commercial undertakings, every man has his own notions about the conduct of his business, and does not want to be interfered with, or dictated to by people who know less about his business than he does himself. Now, while it may be argued in the case of public service corporations that the people who have put their money into these enterprises, have done it with their eyes open and with full knowledge that they were subject to governmental regulation and control, there is nothing in that argument which makes public interference any more palatable to the man or group of men who are interfered with."

This address well expresses the spirit of the railway managers and employees toward all forms of investigation, and the complete lack of understanding, on the part of these managers, of the legal and moral relations which they bear to the communities which they serve. It is extremely unfortunate that railway and corporation people have not taken the public fully into their confidence, and fully and freely given out correct information as to the operation and depreciation of their properties; also, it is unfortunate that, when a corporation official does feel a grievance, he permits himself to make a partisan speech, or write an unwise article for publication. Much hostility is traceable to foolish, undiplomatic sayings or writings of corporation managers (which are often but half quoted), or to equally foolish speeches or newspaper editorials in opposition to the corporations, which are taken seriously by the managers. Whatever may be the cause, there

* *Railroad Age Gazette*, April 16th, 1909, p. 857.

is a regrettable hostility, and, on the part of the corporation officials, there is an apparent unwillingness to admit right motives to anyone advancing theories regarding corporate regulation and control, due largely to the training and atmosphere surrounding the corporate service.

The public has a large bill of particulars, one of which is the promotion of wildcat companies, such, for instance, as the "New York and Chicago Air Line" project which, only a year or so ago, drew from $2 000 000 to $3 000 000 from the people in a limited territory. These people were "investing" in railway stocks. A Federal control of the issue of stocks and bonds would have prevented this and hundreds of like swindles. Any move to secure such a law has always been opposed by the management of large and legitimately operated corporations, under the impression that they are about to be persecuted, and, naturally, the victim classes these corporations with the alleged one that secured his money.

The issue of stocks and bonds far in excess of any possible cost or value of railroad, street railroad, and other properties, and the making of large personal fortunes by the promoters, are matters of such frequent occurrence that it is difficult, indeed, to dismiss them with a mere denial. There is hardly a community of any size which has not had its example of "consolidation," "combine," or "merger," which has resulted in the issue of excessive securities; and there is hardly a citizen of any intelligence who has not either seen or had experience with some form of corporation promotion carried on strictly within the law, but which, nevertheless, in plain language, was a swindle. These, to say nothing of some gigantic deals involving millions, will sooner or later compel some form of regulation of the issues of stocks and bonds. In the last analysis, it is the money of the people, the hundreds of thousands of small investors, depositors in banks, and owners of life insurance, whose money goes into corporation securities, and, until the officers of the great railroads co-operate in securing such forms of control of stock and bond issues as will make impossible the purely speculative "wildcat" corporations, and thus safeguard minor corporations, as to furnish at least reasonable security to those whose money is invested, all forms of corporation security must be under suspicion with the public, and the agitation for control must continue.

It is not, as Mr. Delano says, a case of put your money in with your eyes wide open; it is an effort on the part of the people to safeguard this form of corporate security in such a way that it can be treated as any other form of sound investment. It should not be necessary to require that all investors in corporate securities be financial experts. It is the writer's opinion, based on his observation and professional practice, that the railroads are not generally open to charges of over-capitalization. While there are flagrant instances, the chief culprits are among other classes of corporations. If such be the fact, it would seem that the interests of the great railway corporations would be in no wise jeopardized by sane and reasonable control.

The theory of taxation is that every one shall bear his proportionate burden of the cost of maintaining the government.

Regardless of any opinions that may be held as to the propriety of the methods adopted in the Interstate Commerce Commission's commercial valuation of railroad properties, it will be conceded that the results gave a set of figures for all the States of the Union, secured by a uniform method of computation and distribution. Table 1, which is a compilation from Tables 1 to 11 of Bulletin 21, shows clearly why, in certain States, corporate taxation is a live issue, and if (as suggested by Mr. Williams in his article, elsewhere referred to) amendment of the Constitutions of some of the States is necessary, it is safe to assume that the condition of inequality shown by this table is such as to compel these changes.

It is needless to cite further instances; enough has been said to indicate:

First.—That the corporations and the public have such intimate business relations that a blow at either must necessarily injure the other seriously;

Second.—That the Courts have defined quite clearly the legal relation existing between the two interests;

Third.—That there is lacking a proper spirit of mutual confidence, and the two interests at the present time are generally hostile;

Fourth.—That there have been errors and abuses on the part of both corporations and public; and

Fifth.—That capital invested in corporations is, and should be, the money of the people, and should be safeguarded so as to prevent its loss by manipulation, and insure a fair return.

TABLE 1.—COMPARISON OF ASSESSED VALUATION AND COMMERCIAL VALUE OF RAILWAY PROPERTIES.

State or territory.	Miles of single track.	Commercial value: June 30th, 1904.	Valuation for Assessment.		Ratio of assessed to commercia valuation: Percentage.
			Year.	Amount.	
Alabama	4 669.35	$150 211 000	1905	$53 926 026	35.9
Arkansas	4 126.44	124 626 000	1904	34 709 623	27.8
California	6 262.54	350 694 000	1904	92 378 550	26.3
Colorado	4 976.24	198 261 000	1903	49 492 135	25.0
Connecticut	1 017.72	105 369 000	1904	120 493 648	114.4
Florida	3 555.84	80 467 000	1904	21 817 478	27.1
Georgia	6 304.72	156 603 000	1903	63 105 810	40.3
Idaho	1 461.53	91 877 000	1904	10 115 378	11.0
Illinois	11 622.74	805 057 000	1904	425 709 055	63.8
Indiana	6 917.85	375 541 000	1904	165 863 367	44.2
Iowa	9 859.23	344 847 000	1904	57 535 160	16.7
Kansas	8 811.43	356 356 000	1904	60 093 534	16.9
Kentucky	3 253.00	155 772 000	1904	77 658 040	49.9
Louisiana	3 898.74	123 401 000	1904	29 044 195	28.9
Michigan	8 660.29	277 597 000	1904	196 795 000	70.9
Minnesota	7 811.04	466 734 000	....	.....	....
Mississippi	3 480.25	107 884 000	1902	29 847 640	27.7
Missouri	7 711.05	309 768 000	1903	97 916 869	31.6
Montana	3 267.10	196 209 000	1904	36 759 827	18.7
Nebraska	5 820.88	263 170 000	1904	46 082 853	18.5
Nevada	986.56	43 745 000	1904	13 778 049	31.5
New Hampshire	1 275.97	79 786 000	1904	22 625 000	28.3
New Jersey	2 277.85	333 568 000	1904	231 655 525	69.5
New York	8 297.29	898 222 000	1903	229 582 064	25.6
North Carolina	4 075.00	113 146 000	1904	69 480 974	61.4
North Dakota	3 190.77	123 390 000	1904	22 160 304	18.0
Ohio	9 196.88	689 797 000	1904	133 858 945	19.4
Oklahoma	2 611.03	78 668 000	1905	11 936 317	15.2
Pennsylvania	11 023.24	1 420 680 000	....	.....	....
Rhode Island	211.89	25 719 000	1904	15 832 003	61.6
South Carolina	3 175.28	75 500 000	1903	29 467 716	39.0
South Dakota	3 047.14	49 646 000	1904	14 354 930	28.9
Tennessee	3 480.83	131 166 000	1903	58 536 566	46.6
Texas	11 848.03	237 718 000	1904	95 209 785	40.0
Utah	1 779.69	90 325 000	1904	20 682 461	22.9
Vermont	1 063.25	37 311 000	1902	27 344 020	73.3
Virginia	3 932.33	211 315 000	1904	63 269 623	37.7
West Virginia	2 886.83	201 799 000	1904	28 771 358	14.2
Washington	3 355.83	182 837 000	1904	26 066 949	14.3
Wisconsin	7 048.76	284 510 000	1904	218 024 900	76.6
Wyoming	1 247.70	100 307 000	1904	7 498 232	7.5
Arizona	1 751.35	68 356 000	1904	6 667 349	9.7
District of Columbia	32.00	5 578 000	1904	2 486 024	44.6
New Mexico	2 504.66	8 640 000	1904	8 511 538	9.9
Total, U. S. A.	213 932.13	$11 244 852 000	....	.....	....

In concluding this subject, it may not be amiss to quote the language of the Supreme Court in the Knoxville Water Case (212 U. S., 1), as follows:

"Regulation of public service corporations, which perform their duties under conditions of necessary monopoly, will occur with greater and greater frequency as time goes on. It is a delicate and dangerous function, and ought to be exercised with a keen sense of justice on the part of the regulating body, met by a frank disclosure on the part of the company to be regulated. The Courts ought not to bear the

whole burden of saving property from confiscation, though they will not be found wanting when the proof is clear.

"The legislatures and subordinate bodies to whom the legislative power has been delegated ought to do their part. Our social system rests largely upon the sanctity of private property, and that State or community which seeks to invade it will soon discover the error, in the disaster that follows. The slight gain to the consumer, which he would obtain from a reduction in the rates charged by Public Service Corporations, is as nothing compared with his share in the ruin which would be brought about by denying to private property its just reward, thus unsettling values and destroying confidence. On the other hand, the companies to be regulated will find it to their lasting interest to furnish freely the information upon which a just regulation can be based."

Explanation of Terms.

In order that there may be no doubt as to the exact meaning of the terms used throughout this paper, a few definitions or explanations are submitted:

Appraisal, or Valuation.—These words are used interchangeably, and refer to the engineering work of determining the present worth of both physical and intangible properties of corporations.

Cost of Reproduction.—This expression refers to the estimate of cost of reproducing the physical properties as they exist on the date of the appraisal, all elements entering into the cost being considered as new and not affected by the elements of depreciation or obsolescence.

Cost, or Original Cost.—These terms refer to the actual amount of money paid for the property, either when it was originally constructed, or in its condition at the time of appraisal, the latter case being the original cost plus the cost of additions and betterments, less abandoned, replaced, or worn-out property. This figure ought to be represented by the "book cost," but it is not often that "book cost" and "actual cost" are the same.

*Present Value, or Present Physical Value.**—These terms are used in describing the physical property as reproduced after it is affected by all elements of depreciation or appreciation. The use of the word "value" in this expression is unfortunate, as it may lead to some confusion. It must be kept clearly in mind that, where this term is used, it refers only to physical property as depreciated, and is in no case intended to refer to the final or "fair value" of the property.

* The term "present value," as used in this paper, should not be confounded with its use by bankers or accountants, or with the present worth of a sum of money due at some future time.

Non-physical, or Intangible, Value.—These terms are used to represent those elements, entering into the final worth of the property as a business concern, which arise out of the operation of the property and are not attachable to the physical property.

All the foregoing terms have to do with the determination of the elements which enter into the final value.

What is "value"? In defining the exact meaning of this term, as applied to the property of a public service corporation, many elements must be taken into account. Standard authorities give many definitions of "value," none of which appears to meet fully the requirements of the term as used herein. Before considering the elements which enter into the value of corporation property, or attempting to determine the methods to be used in fixing proper figures of worth for each of these elements, it is proper and necessary to obtain a clear definition of "value," the thing sought to be ascertained by the inquiry.

The term, "commercial value," has been considered in place of "value," but is not used because it is held to be more properly applicable to the selling or exchanging value of fractional interests in the property, and the methods of computing the commercial value of securities which are in common use cannot be adopted in an engineering valuation. The Standard Dictionary definition of "commercial value" is:

"The source of commercial value, according to different schools of economists, is (1) the degree of want felt for a commodity as shown in the relation of supply and demand, (2) the amount of labor embodied in it, or (3) the cost of reproduction. Practically, commercial value is that for which a thing can be sold or exchanged at a given time and place."

The definition given by Professor Adams is:

"The estimate placed upon the worth of a property, regarded as a business proposition."

Both these definitions are in a measure involved, and the writer considers that the term, "Commercial Value," is too narrow and restricted to be properly used.

As a definition of that estimate of worth which an engineering commission should report as the result of a complete appraisal, the writer submits the following:

The value of a property is its estimated worth at a given time, measured in money, taking into account all the elements which add

to its usefulness or desirability as a business or profit-earning proposition.

There are two classes of elements entering into the final value:

(*1*) *The "Physical Property" Element of Value.*—This consists of those things which are visible and tangible, capable of being inventoried, their cost of reproduction determined, their depreciation measured, and without which the property would be unable to produce the commodity on the sale of which income depends. This physical property is considered as an operating entity, and not as collateral of inert and partly worn-out equipment, and, being so considered, carries, as part of the physical value, those costs and charges which are an inseparable part of the cost of construction but do not appear in the inventory of the completed property.

(*2*) *The "Non-Physical" or "Intangible" Elements of Value.*—These are those things which, added to or taken from the worth of the physical property, make up the value, and include whatever accrues to the property by reason of its operation, or by reason of grants, contract rights, competition, or location, which at the time of appraisal affect favorably or unfavorably the worth of the property.

The worth of the physical property is primarily that on which the value of the whole property rests.

While it is clear that the worth of the physical property, being the cost of reproduction less depreciation, is not necessarily the value of the property, it is equally clear that the physical worth must bear some very definite relation to value, and the writer is strongly of the conviction that this relation is such that "value" cannot be ascertained without a determination of physical worth. The physical property element represents the investment on which a fair return is to be earned, and in most cases an appraisal is necessary for the determination of the amount of money actually invested. As illustration of the fact that "physical value" and "value" are not the same, the case of two railroads actually existing and in operation between two cities in Michigan may be cited.

Road "A" occupies a narrow valley through high and abrupt hills. Its alignment is fair for hilly country; its maximum grade is 1 per cent. It has a number of bridges, all short and low. Its cost of reproduction might reasonably be placed at $28 000 per mile. A mining town at one end ships a heavy tonnage down grade to a lake port at the other.

Road "B" was constructed several years later, and, being barred from the only valley, built a line across the hills, involving heavy grading, very long and high steel trestles, a longer line, maximum grades of 2%, and a heavy climb from the mining town to the summit before starting to drop to the lake. The cost of construction was more than double that of Line "A," and the tonnage which can be hauled in either direction is but a small fraction of that which can be hauled with the same power by Road "A." A reasonable figure for cost of reproduction may be given as $60 000 per mile.*

Here is clearly a case where the older, less expensively built road has a value as an earning proposition far in excess of that of the new road. The rate on commodities does not affect the relative difference. A higher rate, while permitting Road "B" to live, greatly adds to the value of Road "A," while the latter can operate at a profit on rates which would not permit Road "B" to pay expenses.

This example indicates the existence of non-physical values, not only positive in the case of Road "A," but also negative as to Road "B."

Many properties have been built in the United States, representing large investments of capital, which are not, and some of which can never be, profitable business investments. In all such the physical valuation will exceed the final value where the property is considered as an operating concern, and a negative factor to cover improper location, uneconomical design, ill-advised investment, or whatever the trouble may be, should be applied.

The physical property is that which enables the corporation to do business. Without physical property it could not produce the commodity which it sells. The amount of money actually invested in acquiring that physical property represents the measure of capital on which it is morally entitled to earn interest and profit; and, in the stage of promoting and financing the enterprise, all hope of earnings is based on the amount of money required to construct the property. These considerations lead the writer to contend that the true method of valuing a corporate property is first to determine the cost of reproduction of the property and its depreciation, and modify this figure by any applicable positive or negative non-physical elements of value.

* In this case, traffic as to Line "B" is limited, and as it is feasible to double-track Line "A" at less cost than Line "B," no advantage can be assigned to Line "B" on account of development of future business

The Michigan State Appraisals.

Organization.

The State Legislature of Michigan, at the session of 1899, passed an act creating a Board of State Tax Commissioners and outlining and prescribing their duties. This act authorized the board to "inquire into and ascertain the value of the property of corporations paying specific taxes under any of the laws of this State."

The object of this valuation was to determine the rate at which the corporations were paying taxes, to the end that necessary laws should be passed so that all taxable properties in the State might be taxed uniformly.

On September 1st, 1900, the Board of Tax Commissioners appointed Professor Mortimer E. Cooley Appraiser of Properties. Immediately thereafter the general organization was mapped out along the following lines of division of labor and responsibility:

1.—Administration.—All matters of general policy in regard to the conduct of the work, all matters relating to negotiations and conferences with officials of corporations, all transactions with the State Tax Commission, the Governor, or the Board of State Auditors, and the entire direction of all relations with the public through newspapers and other channels, were retained by the appraiser, who was the final arbiter on all matters referred to him regarding the details of the work.

2.—Civil Engineering.—The appraisal of all property which in the course of construction would fall under the supervision of the civil engineering department of a road, including land, roadway, bridges, and structures, was in charge of the writer.

3.—Mechanical Engineering.—The appraisal of all motive power, rolling stock, and property which in the course of construction would fall under the supervision of the mechanical engineer, including power and electric plants, shop tools and machinery, water stations, etc., was in charge of Mr. Theodore H. Hinchman, Jr., of Detroit, Mich.

In the matter of the final assembling of figures, computation of percentage values, and compilation of final results, Mr. Hinchman and the writer worked together with joint general supervision.

4.—Telegraphs.—The inspection and appraisal of all telegraph properties was under charge of Mr. William S. Conant, of Detroit, Mich.

5.—Telephones.—The appraisal of all telephone properties was directed by Mr. William J. Rice, of New York.

6.—Vessel Properties.—All vessels belonging to companies whose property was involved by the appraisal were inspected and appraised by Herbert C. Sadler, Professor of Naval Architecture and Marine Engineering at the University of Michigan.

In the following narrative, no special mention is made of the work executed under the direction of Messrs. Conant, Rice, and Sadler, because they really had charge of independent appraisals which were conducted on lines similar to those adopted in the railroad appraisal, and their methods were not different from those of the latter; hence any description of their work would be in a large measure repetition. This omission is in no wise to be construed as any reflection on the importance or high character of their work.

The organization as just outlined, while necessarily touching and overlapping at points, was generally defined so clearly that there was no duplication of work. Each head of department was responsible for the work of his special division, and directed the laying out and execution of the work done by his men.

The first task, after deciding on the general organization, was to determine the general methods to be adopted and the manner of getting the necessary detailed information. The magnitude of the work was appalling. There were seventy-eight different incorporated companies, owning some 10 000 miles of railroad, scattered over 54 000 sq. miles of territory. In addition, there were a number of small unincorporated railroads, telegraph, telephone, plank road, and other corporations, many of which had no records, no complete inventory, and no department organized so that the information could be readily secured. It was determined:

(*1*) To make or secure a complete detailed inventory of every piece or parcel of property belonging to each company;

(*2*) To examine each separate thing, place on it an estimate of cost of reproduction and depreciation;

(*3*) To prepare, as a basis for the final figure of value, an estimate of the present value, being the cost of reproduction less the depreciation.

Having determined on a detailed physical inventory and appraisal, the next step was to outline the work so as to secure absolute uniform-

ity. The difficulties which confronted the appraiser at this period were many, chief among which were:

(*a*) *Lack of Complete Understanding on the Part of the State Officials.*—The Governor and Board of Tax Commissioners rendered every possible assistance, but the Board of State Auditors was not at first fully committed to the work, and the uncertainty as to whether or not bills would be paid, delayed seriously the employment of men and the full commencement of work for 3 or 4 weeks after the first organization was made.

(*b*) *The Attitude of the Railroad Corporation Managers.*—While this was not actively hostile, it was a serious cause of delay, as they could not foresee what effect the work might have on the interests in their charge, and, while not refusing access to their records, they delayed and held back information; in fact, a long time elapsed before all the companies opened their records to the appraiser and his staff.

(*c*) *The Confused Condition of the Records.*—Many small corporations had absolutely nothing in the way of records of buildings, bridges, land, or other properties. Others had very complete records in certain departments and very imperfect ones in others; still others had records which had every appearance of being complete, but they were not up-to-date.

Facing an appraisal of this magnitude, with a time limit of only 4 months for the entire work, with delays at the outset which seriously hampered the organization for 2 or 3 weeks, the appraiser was compelled to occupy this time in preparing the blank forms to be used on the work, and in conducting correspondence with the men who were to make up the working force, investigating their references, etc.

The blank forms, Figs. 1 to 10, were the result of a series of conferences between the members of the staff. By this time it was quite evident that no great amount of help could be hoped for from the corporations. Had it been possible to secure access to the records of such railroad companies as the Michigan Central or the Lake Shore and Michigan Southern before the final drafts of the forms were prepared, the writer believes that several might have been simplified and many improvements could have been made. However, this was not possible, and the forms were prepared and printed before access to any railroad office had been granted.

T. C. Form R.R. 9

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

ALIGNMENT AND PROFILE IN MICHIGAN

_____ *Office Inspector*

_____ *Field Inspector*

DIVISIONS OF ROAD		ALIGNMENT							PROFILE					
FROM	TO	Length Miles	Number of Curves	Aggregate Length of Curved Line Miles	Aggregate Length of Straight-Line Miles	Number of Curves over 3 Degrees	Total Curvature over 3 Degrees	What is Degree of Maximum Curve	Aggregate Length of Level Grades	Sum of Ascents Feet	Sum of Descents Feet	Number of Miles Grade 0.5% to 1%	Number of Miles Grade Over 1%	What is rate Your Maximum Grades and what their length Miles

T. C. Form R.R. 4

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

RIGHT OF WAY AND REAL ESTATE

IN FILLING OUT STATEMENT KINDLY SEPARATE LANDS AND RIGHT OF WAY BY COUNTIES AS FAR AS POSSIBLE

_____ *Office Inspector*

_____ *Field Inspector*

COUNTY	Trackage Right only Miles	WIDTH OF RIGHT OF WAY IN FEET						Total Acreage of Right of Way	Total Acreage Lands own'd by Company other than Right of Way	TOTAL REAL ESTATE	
		Less than 50 Miles	50 to 60 Miles	60 to 70 Miles	70 to 99 Miles	100 Miles	Over 100 Miles				

T. C. Form R.R. 8

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

MILEAGE, RAIL AND TIES

_____ *Office Inspector*

_____ *Field Inspector*

		Total Length in Miles	Total Number of Side Tracks or Spurs	Yard Tracks Miles	Double Track Miles	Rail under 40 lbs. per yard Miles	Rail 40 to 49 lbs. per yard Miles	Rail 50 to 59 lbs. per yard Miles	Rail 60 to 69 lbs. per yard Miles	Rail 70 to 79 lbs. per yard Miles	Rail 80 to 89 lbs. per yard Miles	Rail 90 to 100 lbs. per yard Miles	Rail over 100 lbs. per yard Miles	Number of Ties per mile	Percentage of Oak Ties	Percentage of Cedar Ties	Percentage of Hemlock Ties	Percentage of other Ties
Main Track from	to																	
" " "	"																	

FIG. 1.

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 18

INTERLOCKING PLANTS IN MICHIGAN

_____ Railroad

Date _____

Include all Electric Crossings having full Interlockers.

_____ *Office Inspector*

_____ *Field Inspector*

	LOCATION	Crossing with	Style of Machine	Wheel or Lever	Connections, Pipe or Cable	Number of Levers or Wheels			By Whom Erected	Date Put in Service	Proportion of Cost Paid by this Co.	Proportion of Maintenance Paid by this Co.	
						Working	Space	Total					

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 8

STATEMENT OF CROSSING PROTECTION IN MICHIGAN

_____ Railroad

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

	DIVISIONS OF ROAD		Total Numbers Unprotected Grade Crossings	Number Grade Crossings Protected by Alarm Bells What Device is Used	Number Grade Crossings Protected by Gates. What Device is Used	Total Number of Highway Under Crossings	Total Number of Highway Over Crossings	Total Number of Unprotected Electric Railway Crossings	Number of Electric Railway Crossings Protected by Derailer without Signals on Steam R.R.	Number of Electric Railway Crossings Protected by Derailer with Signals on Steam R.R.	What Proportion do You Pay of Installation or Maintenance of Electric Railway Crossings	
	From	To										

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 1

ENGINE HOUSES AND TURN TABLES

_____ Railroad

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

	LOCATION	ENGINE HOUSES						TURN TABLES					
		Kind of Structure	No. Stalls	No. Pits	Pit Dimensions Feet	When Built		Length Feet	KIND OF TABLE	Foundation	CURBING	When Built	

FIG. 2.

MICHIGAN RAILROAD APPRAISAL

T. C. Form R. R. 2

FIELD INSPECTION REPORT

_____ Railroad

Between _____ and _____ Miles _____ Number of Tracks _____ Ties, C. to C. _____

Date _____

Highest schedule passenger train _____ miles per hour, Freight _____ miles per hour. _____ Inspector

	MILE	GRADE		TIES		RAIL		BALLAST		FENCE		FROGS AND SWITCHES			CROSSINGS		DRAINAGE	ALIGNMENT	REMARKS
		Yardage	Classification	Kind	Condition	Weight	Condition	Kind	Condition	Kind	Condition	Number	Kind	Condition	Number	Condition			

MICHIGAN RAILROAD APPRAISAL

T. C. Form R. R. 7

BRIDGES

_____ Railroad

_____ Office Inspector

Date _____

_____ Field Inspector

Include all wooden, steel or combination trusses, all girders and I beams spans - if solid floor and ballast please so state.

	Bridge Number	LOCATION	NAME OF STREAM	FOUNDATION					SUPERSTRUCTURE									Date Built
				Frame or Pile Abutments	Stone or Concrete Abutments	PIERS	Approx. Cu. Ft. Masonry in Piers and Abutments	Number of Ft. Bridge Seat to Water	Number of Spans	KIND	Length out to out	Specification for Loading Required	No. Panels	No. Size and Kind of Stringers	Size and Kind of Beams	How Supported	Size of Ties	

MICHIGAN RAILROAD APPRAISAL

T. C. Form R. R. 17

DRAW BRIDGES

_____ Railroad

_____ Office Inspector

Date _____

_____ Field Inspector

In this table furnish data as to draw span and pivot piers only - other spans in other bridge record.

	Bridge No.	LOCATION	Name of Stream	Date of Erection	FOUNDATION					SUPERSTRUCTURE					
					Material	Size	Approx. Cubic Feet Masonry	Height Above Water	Approx. Depth Footings Below Water	Length Draw	Kind of Span	Material	SPECIFICATION FOR LOADING	What kind of Power used for swinging	Kind of Turn Tables

FIG. 3.

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

T.C. Form R.R. 10

CULVERTS

_____ Office Inspector

_____ Field Inspector

	DIVISION		Total Number Stone Box Culverts	Total Number Wooden Box Culverts	Total Number Wooden Open Culverts	18 in or smaller Iron Pipe		24 inch Iron Pipe		30 inch Iron Pipe		36 inch Iron Pipe		48 inch Iron Pipe		60 inch Iron Pipe		Iron Pipe over 60 inch			Total No. Sewer Pipe Culverts under 24 inch	Total No. Sewer Pipe Culverts 24 inch and over	Total No. Pit Cattle Guards	Total No. Surface Cattle Guards
	From	To				No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Approx. No. Feet of Pipe	No. of Lines	Size	Approx. No. Feet of Pipe				

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

T.C. Form R.R. 11

ARCHES

_____ Office Inspector

_____ Field Inspector

	Bridge No.	LOCATION	STREAM	Date Built	Length of Span	Length of Arch in feet Face to Face	Height Feet	Approx. No. Cubic Feet Masonry	KIND OF ARCH	KIND OF MATERIAL				
THIS SPACE FOR BINDING														

MICHIGAN RAILROAD APPRAISAL

_____ Railroad

Date _____

T.C. Form R.R. 29

CAR FERRY TERMINALS

_____ Office Inspector

_____ Field Inspector

	GENERAL DESCRIPTION									QUANTITIES					VALUES		REMARKS
	Items	Owner	Used by	Location	Date Built	Type	No. Tracks	Dimensions	Struc. Steel Iron and Mech. furnished by	Iron and Steel Pounds	Bolts and Nails Pounds	Piles lin. feet Kind	Lumber feet b.m. Kind	Excavation Fill, Dredging, Cu. Yds.	Estimated Cost		

FIG. 4.

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

T.C. Form R.R. 20

COAL CHUTES

_____ *Office Inspector*

_____ *Field Inspector*

	LOCATION	Length of Trestle	Kind of Trestle	Foundations	Size of Building	Number of Pockets	Capacity of Pockets	Date Built	Name of Builder	If Hoisting or Conveying Machine in use, State What Kind	

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

T.C. Form R.R. 19

WATER STATIONS

State whether Power is Steam, Gasoline, Wind, Gravity, or Hydraulic Ram

_____ *Office Inspector*

_____ *Field Inspector*

	LOCATION	Source of Water Supply	PUMP			BOILER			PUMP HOUSE				TANK				Length and Size of Suction and Discharge	
			Kind	Size		Kind	Size		Kind	Size		Date Built	Size	Capacity Gallons	Foundations	Date Built		

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

T.C. Form R.R. 28

ORE DOCKS

_____ *Office Inspector*

_____ *Field Inspector*

	GENERAL DESCRIPTION					DIMENSIONS						QUANTITIES				VALUES		REMARKS
	ITEM	Owned and Used by	Location	Date Built	Type	No. Pkts.	Cap. Tons	Hgt. Water to C. L. Hge.	Hgt. Water to Deck	Width	L'gth of Chutes	Rods, Bolts, Iron, Pounds	Piles Lin. Feet Kind	Lumber Feet B.M. Kind	Fill and Dredging	Estimated Cost		

FIG. 5.

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 15

_____ Railroad

Date_____

STOCK YARDS

_____ *Office Inspector*

_____ *Field Inspector*

LOCATION	Number of Pens	Size of Yards Feet	Date of Completion		WELLS				
					Depth Feet	Diameter			

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 14

_____ Railroad

Date_____

TRACK AND STOCK SCALES

_____ *Office Inspector*

_____ *Field Inspector*

LOCATION	NAME OF SCALES	Capacity Tons	Length	Date Built				

FIG. 6.

T.C. Form R.R. 13

MICHIGAN RAILROAD APPRAISAL

STATEMENT OF MISCELLANEOUS BUILDINGS

_____ Railroad

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

Include in this report all shops, warehouses, car houses, watchmen's shanties, flagmen's buildings, elevators, general office buildings and all other structures not specifically asked for in other reports.

LOCATION	DESCRIPTION OF BUILDING	SIZE	Kind of Bldg., Brick, Stone or Frame	Date of Completion		

T.C. Form R.R. 12

MICHIGAN RAILROAD APPRAISAL

STATION BUILDINGS

_____ Railroad

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

LOCATION STATIONS	DESCRIPTION OF BUILDING	SIZE	Kind of Bldg., Brick, Stone or Frame	Date of Completion		

FIG. 7

THIS SPACE FOR BINDING

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 22

_____ Railroad

REAL ESTATE

NOT USED FOR RAILROAD PURPOSES

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

LOCATION		DESCRIPTION	Assessed Value	TOTAL TAXES	
COUNTY	ASSESSMENT DISTRICT			AMOUNT	AMOUNT PAID

THIS SPACE FOR BINDING

MICHIGAN RAILROAD APPRAISAL

T.C. Form R.R. 23

_____ Railroad

MISCELLANEOUS EQUIPMENT

ROLLING STOCK

Date _____

_____ *Office Inspector*

_____ *Field Inspector*

Location	No.	Name	Description	Capacity	Date Built	Cost When New	Remarks

FIG. 8.

THIS SPACE FOR BINDING

T.C. Form R.R. 24

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

SHOP MACHINERY AND TOOLS

_____ *Office Inspector*

_____ *Field Inspector*

Description	Maker	Date Built	Size	Cost When New	Remarks

T.C. Form R.R. 25

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

STEAM SHOVELS, DREDGES, PILE DRIVERS

_____ *Office Inspector*

_____ *Field Inspector*

	MAKE OF SHOVEL	PROPERTY OF	Year Built	Size of Dipper Cu. Yds.	Shop Number	Cost When New	Present Value % of New	REMARKS

T.C. Form R.R. 26

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

DOCKS AND WHARVES

_____ *Office Inspector*

_____ *Field Inspector*

	GENERAL DESCRIPTION							QUANTITIES				VALUES		REMARKS
	ITEMS	Owner	Used by	Location	Date Built	Type	Dimensions	Rods, Bolts Nails etc. Pounds	Piles Lin. Feet Kind	Lumber Feet B.M. Kind	Excavation Fill Dredging, Cu. Yds.	Estimated Cost		

FIG. 9.

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Date_____

T. C. Form R. R. 21

CLASSIFICATION OF FREIGHT CARS

NOTE:—Under remarks specify whether box cars are ventilated, stock cars are single or double deck, gondolas are plain, hopper or drop bottom; also any other special features.

_____ *Office Inspector*

_____ *Field Inspector*

	GROUPS BY NUMBERS	Class, as Box, Furniture, Stock, Gondola, Flat, etc.	Capacity in lbs.	Total weight of car and trucks in lbs.	DIMENSIONS OF CAR BODY: Outside Length over end sills	Inside Length	Inside Width	Inside Height	Superstructure, wood, steel or composite.	Under frame, wood, steel or composite	TRUCKS: Kind	Size of journal	Bolsters, wood or steel: Body	Bolsters, wood or steel: Trucks	Brakes, hand, or air and hand	Coupler, Kind	Date built	Number in service	Cost of each car complete when new	REMARKS
1	No. to No.																			

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Division_____Date_____

T. C. Form R. R. 27

PASSENGER EQUIPMENT

_____ *Office Inspector*

_____ *Field Inspector*

	NUMBER	Class Coach, L.S. S. Mail, Express, Comb.	DIMENSION INSIDE	TRUCKS: WHEELS No.	WHEELS Size	WHEELS Kind	SPRINGS Bolster Size	SPRINGS Equalizer Size	Frame, Wood, Steel or Comb.	INTERIOR: FINISH	Head Lining, Wood, Metal or Canvas	SEATS No.	SEATS Kind	Lights, number and Kind	Closet and Lavatory	SASH Double or Single	Glass Plate or D.S.	Curtains or Blinds	Decoration	PLATFORM: Steel or Wood	Vestibule, Wide or Narrow	Coupler or Hook	Heat, Direct Steam or Heater	BUILDERS	Date Built	Number now in Service	Cost when new	REMARKS

MICHIGAN RAILROAD APPRAISAL

_____Railroad

Division_____Date_____

T. C. Form R. R. 5

LOCOMOTIVES

NOTE:—Cost when new should include original cost of engine and tender plus original cost of all accessories, as brakes, bell ringer, sander, water scoop, etc., added since engine was purchased

_____ *Office Inspector*

_____ *Field Inspector*

	PLACE OF INSPECTION	No. of Engine	Type of Engine	Builder and Class	Size of Cylinder	Weight without Tender, lbs.: Working Order	Weight without Tender, lbs.: Empty	Pass., Frt. or Switch P. F. or S.	When New: Date	When New: Cost	Last Heavy Repairs: Date	Last Heavy Repairs: Cost	Coupled Drivers: Number	Coupled Drivers: Centres: Diam.	Coupled Drivers: Centres: Steel or Iron	Coupled Drivers: Tires: Diam.	Coupled Drivers: Tires: Maker	Kind of Headlight	BOILER: Kind	BOILER: Steam Press. Built for	BOILER: Total H.S. Square Ft.	BOILER: G.S. Sq. Ft.	BOILER: Last New Boiler: Date	BOILER: Last New Boiler: Cost	Steam Heater	Bell Ringer	Sander	BRAKE: Size of Pump	BRAKE: Kind of Brake	BRAKE: Train Signal	TENDER: Water Gallons	TENDER: Coal, Tons	TENDER: Weight, Empty, Lbs.	TENDER: Water Scoop	REMARKS
1																																			
2																																			

FIG. 10.

That a few changes were made in 1904 was to have been expected; that these forms were almost in their entirety made a basis for the similar work of the Wisconsin appraiser, some three years later, was in the nature of a high compliment and goes far toward answering the criticisms of this part of the work, generally to the effect that the forms call for much more information than could possibly be used, and that they show lack of care in arrangement.

It may be said here, properly, that the uncertainty as to the final attitude of the companies made it essential that the appraiser prepare, if need be, to make his inventory by personal inspection in the field. Indeed, this was done in the case of several roads, and, while most of the companies finally accorded every courtesy, either giving the appraiser access to their records, or furnishing the information desired, it is not probable that the shortness of the time limit would have enabled the appraiser to secure any sort of result had a modified plan been adopted.

The law provided no requirement that the companies should furnish any information. In order to secure the data, it would have been necessary to employ a large number of men, and this would have been such a serious expense to the companies that refusal to comply would probably have followed such a request. Many of the companies had no men in their service able to prepare the required data; and, finally, eight or ten men after having worked in the files of companies owning reasonably full records, were much better able to take off the desired data intelligently from the records of other companies than men unfamiliar with the needs of the appraiser and with no prior experience. Then, too, the work secured was that of one body of technical men, all experienced in different phases of railway work, and thus was uniform and consistent. Had seventy-five or eighty different men or sets of men prepared these inventories, there would certainly have been a great variation in their worth and reliability.

It must be kept clearly in mind that lack of time was the main feature which kept the appraiser from considering any such plan of co-operation with the railroads as was adopted later in Wisconsin and Minnesota, and that no distrust of the railroads, or lack of desire to co-operate, had anything to do with the appraiser's decision to use the method which was adopted.

Shortly after the preparation of the blanks, access was granted to

the records of the Ann Arbor Railroad, and almost immediately thereafter several other companies opened their files to the appraiser; the State Board of Auditors determined to pay the bills, as approved by the appraiser; and the initial difficulties were so far removed that it was possible to carry out, without any further delays, the plan of organization which had been perfected.

The personnel of the staff was considered to be of the greatest importance, and, in the selection of men, the requirements desired were: experience in the construction and operation of railroads, thorough technical training, high standing in the Profession, as shown by membership in the American Societies of Civil or Mechanical Engineers, or of other Societies of high standing, and high moral character. Politics, residence in the State, or local influence, had absolutely no weight in the selection of any of the men. In a number of cases men were secured who had for some years occupied the position of Chief Engineer of important lines. In a very large number of cases men who were engaged on this work have since its completion held the position of Chief or Principal Assistant Engineer of important railroads, and practically all of them returned to railway service. Dozens of these men are well known, and their work deserves that full credit should be given to each, but it is impossible to do so within the limits of this paper.

The minor positions, such as assistants in the field and in the computing and compiling rooms, were assigned to younger men, generally with some railroad experience, and in many cases they were graduates of technical schools, Cornell, Yale, Rensselaer, Michigan, Ohio State, and other schools having representatives.

The writer believes that no more harmonious or loyal organization was ever gathered together before, or has been since. Men who had held Chief Engineerships trudged miles in the wilds of Michigan on foot, inspecting and inventorying property, and came into the office and worked long hours at the computing tables with the utmost cheerfulness and *camaraderie*. There was complete harmony, absolute loyalty, and as perfect a spirit of unselfish devotion to the work as the writer has ever seen in any organization.

The fact that such a staff of engineers, of wide experience in railroad construction and maintenance, had been assembled, made it feasible to carry out a plan of the appraiser which proved to be of

great value. At frequent intervals, during the progress of the work, conferences were held which were attended by all the heads of departments and by many of the older and more experienced engineers. Matters of policy, details, general principles, and rules and methods for conducting the appraisal, were fully discussed, and stenographic records were made of the discussion and conclusions. These conferences covered practically every question that arose; they were of such a nature as to draw out the opinions of the men fully and freely; and their effect was to eliminate the error due to individual judgment, and harmonize and unify the methods and results of the appraisal.

Special emphasis has been laid on the organization of the staff, because the criticism has been made that this work was lacking in care, was hurriedly done, and was unreliable. The work must be judged by its results, but the criticism that it did not receive proper care is absolutely unjustified in fact. The men engaged were of the highest type of experienced, technically educated, and highly qualified engineers; they entered the work unreservedly, and gave the best there was in them. The Michigan appraisal was not a one-man job; it was the work of many men, and all are entitled to credit.

That some men in an organization such as this, gathered from all over the United States, should prove to be lacking, and should fail to hold their place with their fellows, was to have been expected. That the number of such men should not exceed half a dozen was remarkable. In fact, almost every such case was found when the first notes were returned to the office, and in only two or three instances was it necessary to send a second man to do work which had been once covered. In several cases men were sent over certain sections which had been inspected by some one else, with a view of getting an idea of the personal judgment of the different men, but in such cases the results were astonishingly close, and created the greatest confidence in the figures of depreciation which were being received.

Looking back on this work, after the lapse of 10 years, after having fully reviewed it twice, and examined all records, after having heard the men engaged on it testify in court, and knowing the record of these men since the completion of the work, the writer believes himself fully justified in stating that, no matter what opinion may be held as to the accuracy, reliability, or value of the result, no charge of careless-

ness, neglect, undue haste, or lack of consideration can be sustained as against the staff.

To strengthen the work further, to eliminate the element of personal error, to guard against the danger of dulled perceptions due to constant application to the work, and to forestall, if possible, every point of objection to methods, a Board of Review was chosen by Appraiser Cooley to whom were referred:

(*a*) The methods of inventory and valuation, as determined by the staff;

(*b*) All points on which special discussion or difference of opinion were noted in the working conferences;

(*c*) Questions as to elements of value in the physical property which were in themselves not tangible or capable of inventory; and finally,

(*d*) The results of the whole work.

The members of this board were chosen on account of pre-eminent standing in the Profession, and on account of experience and prominence in railway engineering. The board was composed of four men, as follows:

Chairman, Octave Chanute, Past-President, Am. Soc. C. E., former Consulting Engineer, Atchison, Topeka, and Santa Fe Railway, but at the time not engaged in active railway work.

George W. Vaughn, M. Am. Soc. C. E., Engineer in charge of Track Elevation in Chicago.

Charles E. Greene, M. Am. Soc. C. E., Dean of the School of Engineering, University of Michigan.

Charles Hansel, M. Am. Soc. C. E., former Engineer, Wabash Railroad, former Chief Engineer, Illinois Railway and Warehouse Commission, and at that time General Manager of the National Switch and Signal Company.

These gentlemen were not engaged in any detailed work on the appraisal; they came to the work for one week each month with minds entirely clear of all confusion raised by issues of detail, and were thus enabled to pass as a court upon all matters laid before them. Their association was of inestimable value in giving confidence to the members of the staff. The many years of railway service of Messrs. Chanute and Vaughn, and their unquestioned ability in that

special field of engineering, gave the stamp of finality to points decided by them. The special knowledge of Mr. Hansel in the field of signal engineering, and his known ability as an expert in organization and administration, were of the greatest value. The service of Professor Greene was that of the analyst and logician; his clear and judicial mind enabled him to formulate the final arguments in many cases under consideration.

The writer wishes to make it perfectly clear that he has not attempted to minimize the work of Professor Cooley by stating the exact relation of the many engineers on the staff to this work, but to bring out and emphasize the fact that no one man, or no two or three men, were responsible for any single part, but that the whole represents the best efforts of sixty or seventy experienced men working to secure a fair, honest, unprejudiced, engineering estimate along such lines as would eliminate, as far as possible, all errors of individual judgment.

It has never been claimed for the work that it was perfect, or that it was entirely free from errors. It has been and is claimed for it that it probably represents as close and conservative an estimate of cost of reproduction and depreciation as it would be possible for any set of men to make under the conditions then existing.

Professor Cooley was in constant touch with the work, knew its every detail, passed upon and approved every rule and order, presided at every conference, and nothing more than his activity, optimism, and constant watchful care and tireless energy kept the force at work day and night and brought about the prompt completion of the details. His recognized high standing, his remarkable ability as an executive and organizer, and his powers of diplomacy, more than anything else, brought about the final acquiescence of the railroad managers and kept up the confidence of the State authorities; his personality pervades the entire work. After giving all due credit to the staff, and they were entitled to much credit, the real honor must go to Professor Cooley. It was his conception, his plan, and the brunt of the battle was his.

Office and Field Methods.

The preliminaries of the organization having been completed, and the forms prepared, a portion of the working force was brought on

the ground, and the work was actively commenced. It was subdivided into four parts:

(*1*) Office inspection, or inventory;
(*2*) Field inspection;
(*3*) Computation;
(*4*) Compilation for the permanent record.

The men chosen as field inspectors were old and experienced railroad engineers. As far as possible, they were assigned for a short period to office inspection, then they were sent into the field, after which they worked at the computation of values; so that each man was engaged on many different phases of the work, and handled the notes of many of his fellows, and no one man made up one complete appraisal, except as specially noted.

Making the Inventories.—Office inspection, or the preparation of inventories, was assigned to parties usually of one or two experienced men with from two to four younger engineers as assistants in the computing-room. These men went to the general offices of the railroad companies and made a complete examination of maps, profiles, bridge and building records, records of motive power, rolling stock, etc. In short, they prepared, as far as it was possible to do so, a complete inventory of every building, structure, or piece of property owned by the road; they took off complete abstracts of real estate and right-of-way records; they noted principal yards and terminals, and secured maps of such as were most complex, or furnished lists of such maps and records as were most essential for the field men, and they made as complete a report as possible of the corporate history of the road and the general condition of its engineering records. No effort whatever was made to examine or audit the financial books of any company, or to secure from such books any data as to cost of property; the work was entirely limited to the listing of physical property.

Most of the railroad companies co-operated, and gave access to their records; one or two filled in the forms; a number had practically no records, and only one or two companies withheld information. Requests for blue prints of large yards and terminals, and of plans of standard structures were generally granted cheerfully, and, although there was no such spirit of co-operation as was shown later by the Wisconsin roads, much labor was saved by the data furnished.

The result of the office inspection was the filing of inventories, which were generally quite complete, the securing of maps and plans, the gathering of data as to prevailing prices of labor and material, and the securing of some very valuable cost data as to special structures and classes of structures. All inventories were made up for roads, or for divisions of roads, with each class of property listed separately, for example, station buildings, interlocking plants, bridges, etc., so that, if necessary, any special class of inspection might be assigned to one man, while to others could be assigned the remainder of the work on that particular road or division.

Office Inspection as a Check on Field Work.—The office inspection furnished many valuable data for checking the judgment of the field men. For example, the number of cubic yards of excavation and embankment on probably the greater part of the mileage had to be secured by the field inspectors, either because the records had not been kept or the changes of line and grade had been so extensive as to destroy their reliability. Every field inspector, therefore, made his own estimate of the yardage of pay earth. The office inspection reports, however, gave reliable data (from profiles or original contract estimate files) of the actual yardage on possibly 2 000 or 3 000 miles of line, so widely scattered that it constituted a check on the work of a majority of the field men.

This work of office inspection disclosed the following points, which will be practically common to all large valuation jobs:

(*a*) There was no uniformity of method in the keeping of records of permanent way and structures;

(*b*) There was a vast amount of carelessness in keeping records up to date, even on the larger roads;

(*c*) The smaller roads, not only had little or nothing in the way of records, but had in many cases no department with employees qualified to make or keep such records;

(*d*) The purchase of new equipment, the construction of new buildings and bridges, and the destruction, sale, or removal of old property, create a condition of continuous change which is seldom recorded by either operating or accounting officials, and makes book inventories derived from the roads of very doubtful value for use in an appraisal.

Field Inspection.—The decision had been reached, after careful discussion, not to permit the field inspectors to place a money value on any structure, but to examine it, make a full description of it in all particulars, and assign to it a percentage which should represent the present value, or the depreciation from a similar new structure rated at 100 per cent.

The field inspectors were furnished with the records of the office inspection covering the district assigned. They were given notebooks, tape lines, and various blanks for reporting progress and recording original estimates in the field. Provision was made for inspection by the field men, either by the use of hand-cars, gasoline inspection cars, or velocipede cars, although, with one or two of the roads, no satisfactory arrangement could be made, and the men were compelled to go on foot. A careful inspection of every structure was made. If any correction to the office inspection record was necessary, it was made; if the structure was new, it was carefully measured and described, and everything noted which would be of service in estimating its value. Side-tracks were measured, and the weight and type of rail noted. All culverts and bridges were examined, described, and their condition noted. Estimates were made of excavation and embankment, clearing and grubbing, etc. (based on the standing timber at the time of the examination), and careful estimates were made of classifications of material. The records of the field inspector generally contained only the description and the percentage, but, occasionally, when apparently valuable information as to cost of any particular structure was available it was noted, as was special information of local matters affecting the value of any part of the work.

It was the plan (carried out with but few exceptions) to complete the record with the field inspector so that from his notes a full and accurate descriptive inventory might be made. There were a few exceptions to the general method of field inspection work as outlined, which were:

Special Work on the Chicago and Northwestern Railway.—The Chicago and Northwestern Railway had no records of any sort, all construction papers having been destroyed by fire. This company organized and placed in the field four complete engineering parties, each under one of its own engineers, and with each party was sent one field inspector. The line was carefully surveyed and cross-sec-

tioned, and complete records of every building and structure were made, side-tracks were measured, and data taken for rail and ballast charts, etc. All work was done in the presence of the field inspector, and he was given copies of all notes. He placed his own percentage of depreciation on everything. The estimates, made up independently by the Chicago and Northwestern engineers and the appraisal staff, using in the latter case the same unit prices as applied elsewhere in the Upper Peninsula, varied less than 2 per cent.

Special Valuations.—Certain special structures, such as ore docks and ore and coal handling machinery, were of such a character as to require expert appraisal. These were examined in the field, appraised, and valued by G. H. Hutchinson, M. Am. Soc. C. E., whose special training and experience in such work had qualified him perhaps better than any other man. Interlocking and signaling plants were specially appraised by the late Elliot F. Moore, who for 10 years had been Engineer of the Michigan Railroad Commission, and whose intimate personal knowledge of almost every plant in the State specially qualified him for this work.

Some of the bridges were of such a character as to require expert knowledge, and this inspection was assigned to William Dunbar Jenkins, M. Am. Soc. C. E., a man of ripe experience and sound judgment. The larger and more elaborate station buildings were examined and appraised, and values finally placed by Mr. F. G. Susemihl, Chief Architect of the Michigan Central System, whose special work in railway buildings made him thoroughly familiar with these values.

Work equipment and special equipment were appraised by Mr. G. L. Lewis, who had been connected with the Marion Steam Shovel Company for many years.

Except for these special assignments, all the field inspection was handled in accordance with the appraiser's plan.

As stated previously, in only two or three cases was it necessary to re-inspect, and, while several sections were intentionally gone over a second time, without letting the field inspector know who had done the work previously, or what his percentages had been, the result of all these checks was to justify the figures in the earlier inspection and to strengthen confidence in the work.

The field inspection of the Mechanical Department involved examining and placing a percentage value on each locomotive, passenger car, and piece of special equipment, and on all shop machinery. Inasmuch as several points of special interest are involved in this inspection, it will be discussed at more length in the section of the paper relating to the methods of work of the Mechanical Department.

Computation.—After the completion of the field inspection, all notes were placed in the hands of the computing force. This organization consisted of two classes of men, engineers brought in from field inspection, and younger engineers. All computations were made independently by two men, and all work was checked carefully.

Every man in the computing room was furnished a large bound blankbook, in which he was required to make all his notes and computations, no figures of any sort being made on loose paper. The name of each man was placed on his notebook, and each set of field and office inspection notes worked upon by him was signed with his initials. It was easy to trace the work of every man, and in the subsequent trial of the Tax Cases, every man in the service returned, and, not only testified as to his office and field inspection, but was able to turn to and identify all the computations made by him, and produce his original figures and memoranda.

Very soon it became evident that such a volume of reports, notebooks, memoranda, maps, plans, pamphlets, and other data was being accumulated that, unless a special system was developed for filing and handling in the office, the confusion would be serious and costly.

Filing in Office.—The system of filing and record keeping had the merit of being simple and inexpensive. There was borne in mind, in devising this plan, the necessity of keeping all papers connected with one division of any road together, the need for reducing to a minimum the labor of filing and indexing, the constant use of papers, and their frequent withdrawal from the files, making it necessary that they could be at once located when they were not in the files.

The vault in the appraisers' office was arranged so that large manilla envelopes, each of sufficient size to hold all the reports, notes, maps, etc., of each road or division, could be filed vertically. Each road was given a number; if there were several divisions, each division was given a letter, as "15-*A*," "15-*B*," etc., and each division was filed separately.

Every report, book, map, or other paper was stamped with its road or division number and letter, and given a sheet number. In this manner every paper was identified, and could be at once placed. A record was kept in a book, describing every paper filed in each envelope.

In issuing papers for work, the entire file was taken and kept together at all times.

One man had charge of the filing and recording, and no one else was permitted to enter the vault. When a file was withdrawn, a receipt was taken, and was put in the place of this file; and when the papers were restored to the vault the receipt was destroyed.

The system proved adequate, and was much less cumbersome than a more elaborate system of card indexing of separate papers could possibly have been.

The net result of office and field inspection had been an inventory based on the railroad records, checked by a man in the field, with a percentage representing the field inspector's judgment as to depreciation, together with a considerable number of special data as to original cost, etc. It was now necessary to place figures of estimated cost of reproduction and depreciation in terms of money.

The State of Michigan is made up of two peninsulas, widely separated, with radically different conditions prevailing as to certain items of the cost of construction.

Computation Tables.—This appraisal involved seventy-eight incorporated and forty-seven unincorporated railroads. It was necessary to adopt such a system as would apply uniform methods and prices to all like property. Accordingly, the field inspectors were assembled, and, after conference, it was determined to prepare a set of tables, covering all classes of railway construction, material, and structures, values being computed for 100% value, and for each 10% depreciation. These tables covered different weights, sizes, and types of structures and material, and were all computed on the basis of the agreed estimated cost.

Unit Prices.—The unit prices were the result of a most careful study and discussion. For many items, such as clearing, grubbing, earthwork, masonry, etc., the price was fixed by agreement during the discussion at a figure which represented the fair average cost of this particular item during the 5-year period preceding the appraisal.

For rails and rail structures, an average price was secured from market quotations for a period of 10 years, a price was determined as the value of scrap, and the percentage of depreciation was applied to the wearing value of the rail. The unit price was $28; the agreed scrap value was $12, leaving $16 as the wearing value of the rail. If an inspector reported rail at 90%, or at 30%, this percentage was taken from the $16 wearing value and to this was added the scrap value. The tables were arranged so that, for any weight of rail and any percentage, the cost of reproduction and the present value could be taken from the tables in dollars per mile. The same was true of bolts, spikes, angle-bars, fish-plates, and frogs and switches.

In the case of material such as ties, where no scrap value could be attached, the percentage was applied directly to the first cost.

In the case of bridges, the tables gave weights per foot and per span for various lengths, types of structures, and loadings, and only the cost of reproduction was estimated.

Estimated costs per cubic foot were deduced for buildings of various standard railroad types and per square foot for depot platforms. These figures were obtained by reducing to this basis the cost of a large number of buildings of known cost, by comparison with data obtained from railroad companies and from a number of engineers who had kept such records, and by consultation with architects. These building tables did not apply to the more elaborate and costly structures, all of which were appraised specially.

Ballasting, track laying, and surfacing were divided into three and four classes, in order to cover the different general types of railroads, and prices per mile were fixed. On Upper Peninsula roads ballasting was estimated at a higher price than on Lower Peninsula roads, while ties and timber construction were estimated at a lower figure.

In addition to these prices, secured by averaging several years' quotations, or by agreement of experienced construction engineers, many valuable figures were obtained from manufacturers of locomotives, cars, mechanical equipment, and bridges; and in several cases access was given to the mechanical cost data of the larger roads. Specifications for locomotives, cars, and shop tools were sent out to builders with a request that they give average prices for a period of years.

From all this mass of data the unit prices for the valuation were determined. For locomotives, values were plotted for engines of different weights, in order to establish a curve, and curves representing deterioration, scrap value, and major repairs were also plotted, so as to ascertain diagrammatically the value of an engine of given weight and stated condition.

The tables and diagrams proved of incalculable benefit in reducing the work, and in securing that absolute uniformity of method necessary to give the appraisal standing.

It may not be amiss to state here that in such a work no set of unit prices could possibly be adopted which would not work some apparent injustice. A number of Michigan lumber roads were of the cheapest possible type of construction, and any unit price applied to ties or timber, which would be at all reasonable for such roads as the Michigan Central, Grand Rapids and Indiana, Pere Marquette, and others, would be far in excess of the actual money paid out by these little roads. A few individual instances of such apparent discrepancy were cause of complaint and criticism, but, on analysis, very generally, these did not appear to be anything but a disagreement with book values, in which ties cut off the right of way were treated as having no cost; or in some similar item certain local conditions may have made the first cost so low as to amount to a donation of property. Conceding the propriety of the objections, the reason for making the appraisal was to furnish information on which the legislature might determine whether the State should go from a specific to an ad valorem basis, and in view of this purpose the objections became unimportant, as they applied to but a few miles of road.

Classification.—All work of computation was classified in strict accordance with the Interstate Commerce Commission's classification of construction accounts, to which were added one or two classifications not recognized by that Commission, and final summaries were returned on sheets similar to those illustrated by Figs. 1 to 10.

In computing, the staff made use of all data of every nature which was before them, checked the judgment of the field inspector wherever any reliable data were furnished, took into account age, special notes, or costs, and, in case of any serious discrepancy in his percentage, reported to the head of the department for either a re-inspection or for a conference with the appraiser and inspector. In this depart-

ment every possible safeguard was thrown around the work to insure its absolute mathematical correctness, and to guard against errors in the personal equation.

Compilation.—After the calculations were checked and completed they passed to the compilers, who arranged and classified them, and prepared the form of the final report. This consisted of a detailed list of every piece of property and every structure, with a short description and specification, and a statement of estimated cost of reproduction and present value. The division is made by roads, by divisions of roads, and by counties. This was done after the completion of all other work, and the disbanding of the organization, a small force being retained by the State to compile and put in permanent form all the papers of the appraisal. This work was done under the direction of Messrs. James Walker and O. C. Le Suer in consultation with Professor Cooley.

The final compilations were typewritten on large sheets and bound, and constitute the final record of the physical valuation. After the completion of the 1900 appraisal, all papers connected with the work of the computing office were arranged in proper order and bound.

Special Problems of the Mechanical Department.

The Civil Engineering section dealt wholly with fixed property located entirely within the State; and the work offered no special difficulties in the way of assignment of values. It is true that, when the question of terminal values was under discussion, the Wisconsin and Michigan Railroad offered a very pretty example, in that the revenue-producing half of its mileage lay in Michigan, while its shops, yards, docks, and car ferries, comprising the great bulk of its physical property, were in Wisconsin. This instance merely emphasized the fact that no State valuation of an interstate property can settle finally and definitely all the questions that arise.

Assignment of Value to States.—The Mechanical Department was compelled to handle the valuation of moving property, and to assign values as between the States on such a basis as would be fair to all parties. The Courts have been inclined to view the distribution of values between territorial units on the track-mileage basis as being a fair one. The study of the problem in Michigan indicates that

while this method, perhaps, is just in most cases, it will not hold in all. Assignment was made upon several bases, as follows:

(*a*) Main-line mileage;

(*b*) Total track-mileage;

(*c*) Car- and locomotive-mileage of equipment operating in Michigan;

(*d*) Car- and locomotive-mileage, entire equipment;

(*e*) Freight-car mileage of the entire system.

The results secured by these different methods show, in many cases, very little difference; all are close, and no injustice is worked by any method, while, in other cases, the figures are widely divergent.

The Lake Shore and Michigan Southern Railway owns a high-class main line between Chicago and Buffalo, and for part of the way there are two lines several miles apart; the entire line is double-tracked, and there is much third track. None of this line is located in Michigan, except some 80 miles of single-track main line of the Michigan Division between Toledo and Elkhart. The company, however, has several hundred miles of branch line in Michigan, which comprises most of the branch-line mileage of its system. These lines, generally, are far inferior to its main line.

Any apportionment of its equipment between States on the basis of either line-mileage, total track-mileage, or locomotive- and equipment-mileage of total equipment will result in the assignment to Michigan of a value far in excess of a proper or fair amount. An apportionment of locomotive and passenger-car equipment on the basis of equipment-mileage or equipment operating in the State, and for freight cars on the basis of car-mileage of total equipment, was found to be most fair.

In making the assignment of values, this study was made for all interstate roads, and such basis used as was apparently most fair in each case, the department making a special effort not to assign to Michigan undue values or those which could not be sustained.

Freight Car Inspection.—One of the most perplexing problems which was faced by the Mechanical Department was the proper and satisfactory inspection and valuation of freight equipment. The freight cars owned by the companies were scattered over the United States and Canada, and the inspection of any considerable percentage of those owned by any company was, of course, an impossibility.

The fact that these cars had been purchased in series, so that there were considerable numbers in a group, all of the same age, and built according to the same specifications, made possible a valuation by groups. The acceptance, however, of any arbitrary percentage of depreciation by years, or the acceptance of the rules of depreciation of the Master Car Builders Association, without making independent investigation with a view of establishing the correctness of the rule, appeared to be unwise.

The several companies submitted carefully prepared statements of equipment. These statements were compared with the equipment register and the reports to the Commissioner of Railroads. The prices used were those of the rules of interchange of the Master Car Builders Association wherever applicable.

Prices were furnished by the leading manufacturers, and in many cases were secured from the books of the railroad company.

In order to determine the condition of the equipment, the inspectors of the department personally examined 32 000 freight cars in Michigan and adjoining States. Their reports were separated, classified, and analyzed by groups, with the result that the inspection fully confirmed and justified the use of the rule for depreciation of the Master Car Builders Association, which was therefore applied. In the 1902 appraisal this rule was accepted without any inspection or further study of the problem.

The criticism of this part of the work by the appraiser of the State of Washington is wholly unjustified, as the work was necessary in order to qualify in Court and defend the rule adopted, and the actual cost of the work was small.

Locomotives.—The inventory of locomotive equipment was secured from the companies, and checked against reports and the equipment register. Personal inspection was made of every locomotive in the State, then a complete description was prepared, and the percentage of depreciation assigned. Curves of depreciation had been computed and plotted, and the figures of the inspectors were compared carefully with the curve in order to eliminate possible errors.

Vessels.—Professor Sadler's appraisal of vessels involved a personal examination of every vessel. This survey included:

(*a*) The hull of the vessel and general equipment;

(*b*) The machinery and boilers.

An independent estimate of the cost of reproduction and depreciation was made, and, wherever possible, this was checked by comparison with the detailed original cost. In case of material difference, various shipbuilders were consulted, and independent estimates of cost were secured. In every case these latter estimates were confirmatory of the estimated cost of reproduction, which figures were used throughout the appraisal.

Overhead Charges.

There are certain expenses connected inseparably with the construction of any public work, which, on the completion of that work, are not capable of physical identification, but which, nevertheless, belong to and must be a part of the cost of the physical property. These expenses are legitimate; and, as long as the property is operated, a very large part, if not all, of the entire expense remains in the present value of the property as a "going concern."

Appraiser Cooley and his staff took up the discussion of these items and disposed of those which were carried into the valuation by the placing of a percentage. These items are:

Engineering.—This covered all the cost of preliminary and location surveys, design, and supervision of construction of the work, and all expenses connected therewith. This was covered by a charge of 4% of the cost of reproducing the permanent way and structure, but not the equipment.

Legal Expense.—This item is inseparable from the construction work, and was fixed at one-half of 1% of the cost of the same items as affected by the engineering charge.

Organization Expense.—This covered the cost of promotion, financing, and general supervision of construction, together with general office expense. These items were covered by an application of 1½% of the cost of the above items.

Interest.—This item is intended to cover interest on money during the period of construction. The length of time taken to build would, of course, be variable. It was assumed that 3% on the entire cost of construction and equipment would be conservative, and this figure was used.

Discount on Bonds.—This was not included, for the reason that it was considered, not as a proper capital charge, but rather as an adjustment of the interest rate to the existing market

condition, and as chargeable to interest account and not capital.

The discussion among members of the staff indicated such a wide range of opinion as to the proper percentages to apply, that the final determination of the rates was passed upon by the Board of Review. There can be no question as to the propriety of these items as proper elements in the first cost of construction of a new railroad. On the theory that the cost of reproduction of the physical property should include every item of expense which would enter into the cost of reproducing the property as it existed on the date of the appraisal, they are proper terms to include in the appraisal. As to whether the fixed rates were high enough in every case, is an open question.

The Charge of Ten Per Cent. for Contingencies.—Perhaps no single feature of the Michigan appraisal of physical property has been so generally criticised as the charge of 10% of the entire estimated cost, including all the percentage charges, to cover "contingencies."

At the time the first appraisal was made, the writer was not at all satisfied that such an item, in such amount, should be included. The reasons advanced were so strong that it was done, and the writer's subsequent work has fully convinced him that it was proper and justifiable, because:

(*a*) The conditions under which this particular inventory and appraisal were made, as to time and lack of co-operation of the companies, made it practically certain that some items of value were missed in the appraisal, such as station and miscellaneous equipment, frogs, switches, track structures, buildings owned by the companies and occupied by others, etc.

(*b*) That there were many and large elements of physical cost not ascertainable by a physical inspection, such as deep foundations, many thousands of yards of earth in swamps and sink holes (a very general condition of roads in the Southern Peninsula), concealed classification due to growth of grass or washing of banks, and many other cases of work actually done, invisible after a lapse of years. The writer knows of many such instances on property which was in his charge many years ago; in several cases there were expenditures of from $20 000 to $50 000 which are now entirely invisible to an engineer passing over the line.

(*c*) The failure on the part of railroad companies to keep anything like a complete history of construction operations, and the changes of operating officials from year to year, cause the loss of record of practically all the expense due to extra hazard and risk which the construction engineer provides for by his "contingencies."

(*d*) The inclusion in operating expense, every year, of sums which are properly construction, and which, if added to unit prices of construction work, would cause the cry that such unit prices were too high. For instance, the appraisal estimate on earth was 17 cents per cu. yd., with no allowance for overhaul. Very much of the grade in the State had actual costs far in excess of this figure, and practically every road spends a large sum annually for the first four or five years, which is charged to operation but is in reality a part of the cost of completing the roadbed.

(*e*) No account was taken of appreciation of any of the elements entering into a road. There is no doubt that roadbed, for example, does appreciate, due to ballasting and track work. These items go far toward accounting for the contingencies item on an old road such as the Michigan Central.

(*f*) There is a considerable amount of cost, which cannot be taken out of capital, where facilities are abandoned or line or grade changed. These changes are common to all growing roads; they are due to the demands for greater traffic; they are necessary to the welfare of the community served; they are often made at points where no charge of defective design will apply. They might be termed expenses due to the development of the State, and, in the development of the railroad business, they were absolutely necessary for its present standard of efficiency. They are incapable of exact and definite determination, and must of necessity be included as contingent expenses.

In the case of a new road, where the exact cost is ascertainable, the records have been fully kept, the original plans are on file, and the history is fresh in the minds of the officials, it will be readily admitted that a charge for contingencies in large amount would not be justifiable; but, in the case of the Michigan Central Railroad, a line more

than 50 years old, which has changed, rebuilt, and added largely to its property; in the case of the Pere Marquette Railroad, made up of the union of a dozen lesser properties, without any complete history; in the case of dozens of little lines, without maps, profiles, or records, some such allowance is fully justified and proper.

The experience of the writer, in the years that have passed since these appraisals, leads him to the opinion that the difficulty of estimating values on an old property are such that in many cases an appraiser might add, with perfect propriety, even more than 10% for the contingency item.

In computing overhead charges, no allowance was made for working capital, and no addition to the physical valuation was made to cover any such element as "going concern" value.

Right-of-Way Values.

Land values were the subject of a great deal of discussion during the appraisal of 1900, but subsequent investigations as to actual railroad purchases resulted in quite radical changes in some of the figures in the later valuations. In view of the fact that many criticisms of these values have been made by railway attorneys, special emphasis is here given to the subject. The conclusions reached in Michigan in 1902 agree so closely with the conclusions of Taylor in Wisconsin and Morgan in Minnesota that it is thought advisable to give a rather full account of the methods used in both appraisals, and the line of reasoning which brought about the changes made in 1902.

The 1900 appraisals methods were as follows: Work in Detroit, Grand Rapids, Saginaw, Bay City, and some other large cities was assigned to special appraisers, who visited the cities, examined critically all the property, conferred with leading real estate men and experts in values, and placed an estimate per acre or per square foot. This part of the work was done with great care, and was substantially unchanged in the later appraisals.

In all other land valuations, in cities and villages, and country right of way, a personal examination was out of the question without making a very large and expensive addition to the staff, as the field engineers generally were not familiar with realty values, and could not take the time to make the large number of inquiries. The appraiser did not see his way clear to organize a special department, therefore

the matter was turned over to a sub-department of the Civil Engineering Section, the work of which may be briefly outlined, as follows:

Lands were classified as:

(*1*) Farm land,
(*2*) Barren land,
(*3*) Villages having a population of less than 500,
(*4*) Villages from 500 to 3 000,
(*5*) Cities having less than 10 000,
(*6*) Cities having more than 10 000.

The percentage of waste land was fixed as a result of interviews with roadmasters, superintendents, and other officials and employees of the roads, by reports from field inspectors and others.

Letters of inquiry were sent to real estate men and bankers in every county in the State (some 500 being communicated with), as to land values in the town or county of each. The responses, which were numerous and indicated considerable care in preparation, were classified, and on these data, supplemented by as much personal inspection as it was possible for a few men to give in a limited time, the values of the various classes of land were determined by a system of averages. The naked land values were then taken, and to them were added, as follows:

South of a line east and west through Saginaw, 125% plus a fixed charge varying from $8.50 per acre downward was added to the so-called naked land values for farm land. No waste land values were considered in this district. North of this east and west line: Farm land, 100% and a fixed charge of $3 per acre and upward; waste land, 200% plus a fixed charge of $3 per acre; for all village lands, 125% plus $8.50, fixed charge; for all city lands, 100% plus $8.50, fixed charge.

The fixed charges were intended to cover the expense of acquiring abstracts, recording deeds, etc. Slightly different figures were made for the Upper Peninsula.

The result of this work was a set of very low figures in many counties, the average price per acre hardly reaching the going price of improved farm lands. There was so little time to review these figures after they were in shape that they were used in 1900, although the appraiser was convinced that they were generally too low.

In the appraisal of 1902 a very careful study of real estate values was made. The offices of Registers of Deeds in ten or twelve counties were visited, a careful abstract of all railway transfers for a period of 10 years was taken off, the acreage determined, the average price per acre for different classes of land computed, and then a very careful study of transfers of adjacent improved and unimproved lands was made. As a result, material increases were made in the farm land values, waste land values were eliminated, the 1900 valuation, made by special appraisers in large cities, was practically unchanged, while very radical changes in the way of equalization of values of lands in villages and small cities were made.

Inasmuch as the 1902 valuation was at issue in the Courts, the writer believes he is justified in discussing at some length the deduction of the staff on the conclusion of the 1902 preliminary studies, which led to the final adoption of the new figures.

One would fall into error if country values for farm purposes were conflicted with country values for railroad purposes. There is, undoubtedly, a close relationship between the two classes of values; this the writer has endeavored to discover, and it is indicated in Tables 2 to 6. The use to which land is put can and does change its value. Farm land in a certain township may be worth $50 per acre for farming, but the discovery of oil would affect values, as far as oil purposes are concerned. The presence of a vein of coal would give a distinct value for mining purposes. Farm prices would not govern values for any special use, such as oil drilling, mining, or railroad operation.

In the case of city business property, farm prices cannot be applied, as the use to which the land is put and the buildings placed on it give it a greatly increased earning power, and hence increased value. Thus, with a railroad right of way, the continuity of the strip of land, the severance of lands crossed by it, the greater earning power it derives from the construction placed on it, in short, the uses to which it is put, give it a value far in excess of adjoining lands. An excellent proof of this is found in the fact that many thousands of miles of right of way have been bought by promoters and either sold to a company, which built the lines, or used in financing the road. In no case has the selling price been based on farm values.

It is not contended that railroad land values do not bear a direct relation to land values for other purposes, as those things which tend to

increase general values usually make the construction of a railroad profitable, and the better and more fully developed the country, the greater is the need for transportation facilities and the higher the prices of land for all purposes. This is shown in the figures submitted herewith.

For purposes of appraisal, therefore, in 1902 the average value, as derived from the 1900 appraisal, was taken, and, by comparison with actual purchases, an attempt was made to ascertain the relation existing between the appraisal figures of 1900 and the usual purchase price for railroad properties, as determined by actual transfers. In making these figures the appraiser was forced to the following conclusions:

(*1*) That the naked land value is not a proper one to use in country lands, but that the going value of country lands with all improvements should be used as a basis for computing the added increment due to railway use;

(*2*) That a classification of farm land and waste land should not be made, except as a basis for arriving at the relative differences in quality of land in different sections of a county;

(*3*) That the added value for railroad purposes is due to the three elements:

(*a*) Continuity,

(*b*) Severance or damages,

(*c*) Changed earning power,

all of which the farmer or owner has cognizance of in making his price;

(*4*) That in making up land values, account should be taken of:

(*a*) The cost of acquiring the land, or expense,

(*b*) The cost of the land itself.

The reasons are:

1.—In making a price on a 40-acre farm, the owner does not make two prices, one on land and one on improvements. He arrives at a flat price per acre for the entire farm, and usually asks more per acre for a part than the whole. A man who valued his land at $100 per acre, with improvements, would hardly sell 5 acres from a corner of his land, even for residence purposes, at naked land prices.

The 1900 appraisal was based on naked land prices, as estimated by a number of citizens of each county, and this flat rate was used in

making figures for the so-called "Market Value of Right-of-Way." It is fair to assume that a railroad company can purchase large tracts of land for gravel pits, or a narrow strip adjoining and widening its existing right of way, at about market prices, as the elements of severance, abutting damages, etc., are absent. Prices for this class of land ought to be, and usually are, lower than those paid for a new right of way.

TABLE 2.—COUNTRY LAND.—ADDITIONAL STRIP FOR WIDENING RIGHT OF WAY, GRAVEL PITS, ETC.

County.	Description: Road and purpose.	Average per acre, 1900 appraisal.	Average per acre, transfer.
Jackson	Michigan Central. Widening right of way	$84.47	$156.08
Kalamazoo	Michigan Central. Additional right of way near Augusta	89.41	140.00
Kalamazoo	Grand Trunk Western. Additional strip for double tracking	94.59	120.50
Cass	Michigan Central. Gravel pit	84.97	94.15
Cass	Grand Trunk Western. Additional strip for double-tracking	71.79	203.53
Berrien	Michigan Central. Additional right of way	109.40	113.66
Washtenaw	Michigan Central. Additional right of way	49.35	130.68
Washtenaw	Ann Arbor. Additional right of way	88.60	116.12
Ionia	Pere Marquette. Gravel pit	77.50	125.00

Actual purchases are averaged from recent transfers, and represent consideration paid owners, but not cost of acquiring.

The 1900 appraisal averages show country land after fixed charges and percentages are added.

The tables given herewith are summarized from a very large mass of information introduced as evidence in a suit of Michigan Central Railroad *et al. vs.* Powers (The Michigan Tax Cases), and are selected as average examples of conditions throughout the Southern Peninsula.

It is evident from the figures in Table 2 that no such naked land values as those used in 1900 were considered by the farmers in placing values on their lands, as the sales covered in that table do not involve any large element of damages. All transfers are of a strip a rod or more in width adjoining an existing right of way.

II.—It is true that in some sections of Michigan there are large tracts of barren or low-priced land. In 1900 barren land prices were used, and were much lower than farm land; in the poorer parts of the State large percentages of barren land were used. This fact brought the average per acre of country land, as applied in the appraisal, very low in many of the counties, and justified the appraiser in using the average country price of 1900 as the base price for a revaluation. Generally, the 1900 appraisal averages for country lands were fair indices of the difference in actual value in different parts of the State.

In the 1900 appraisal, the Michigan Central was credited with having, in Jackson County, 309.1 acres of farm land (naked value, $38, average rate $93.30), and 34.35 acres of barren land at $5 per acre. The field inspectors reported that part of the district between Parma and Albion, in the vicinity of Bath Mills, was waste or barren land. The Jackson and Battle Creek Traction Company parallels and adjoins the Michigan Central Railroad right of way from Parma to Bath Mills. An investigation of records of deeds showed that they bought 25.02 acres of land in this district at $65.79 per acre, and that the average price of all their land in the county was $239.52 per acre.

While there was a marked difference in the rates of different grades of country land, no one would be justified in putting any land south of a line drawn from Saginaw to Muskegon at prices as low as $2 to $10 per acre. An average based on the 1900 classification of lands would probably eliminate all waste land classifications, without doing any injustice.

TABLE 3.—AVERAGE VALUES PER ACRE OF COUNTRY LANDS, OF THE 1900 APPRAISAL, OF THE JACKSON, LANSING AND SAGINAW RAILROAD, AFTER ALL THE PERCENTAGES AND FIXED CHARGES WERE ADDED.

County.	Price.	County.	Price.
Jackson	$75.71	Ogemaw	$8.69
Ingham	74.90	Roscommon	10.74
Clinton	42.38	Crawford	8.41
Shiawassee	67.18	Otsego	15.62
Saginaw	40.80	Montmorency	12.38
Bay	38.69	Cheboygan	17.13
Arenac	32.47		

Table 3 illustrates quite clearly the extremely low figures applied in many counties in the 1900 appraisal, and also represents quite well the relative difference in value in the different counties.

That the 1900 rate varies about as the purchase price, is shown by the fact that the Pere Marquette Railroad built a line in Montcalm County, buying 155.3 acres at an average price of $135.19 per acre, while the 1900 appraisal showed an average of $29 on the 918 acres appraised. The purchase price was 4.66 times the 1900 appraisal.

In Calhoun County, the Grand Trunk Railroad bought 63.2 acres at $491.13 per acre, while the 1900 appraisal was $61.44 on all the country land in the county, or only one-eighth of the actual purchase price.

III.—There can be no doubt that a railroad right of way costs much more than an equal acreage of farm lands. The writer has always been inclined to hold the view that an ordinary right of way through good farming country would cost from two to three times farm prices, no matter how much care is used in the acquisition of the land. In recent years the price of right of way has been greatly increased. The Newton and Northwestern Railroad right of way, in Iowa, cost $267 per acre, on a line 80 miles long. This is nearly all country land, about 1 mile in the outskirts of Boone (population 12 000), and about ½ mile in Newton (population 6 500), being the only city land to increase the average. The Rock Island System and the Chicago Great Western paid higher country prices in the same territory. This line is in such country as Southern Michigan, and land is held at from $65 to $100 per acre.

The Toledo Urban and Interurban right of way, in Lucas County, Ohio, was bought by the writer in 1904 at an average net price of $329.21 per acre. The average assessed valuation is $55 per acre. The going value of farm lands will range from $100 to $225; probably a fair average is $135 per acre. The prices paid by Michigan railroads are fully sustained by these personal experiences.

The figures in Table 4 show that the actual average price paid for new right of way is greater than the average of the 1900 appraisal, after the 125% and fixed charges are added, by from 230 to 726 per cent.

The argument that a change of line costs more than a new line is not sustained by Table 4. In Jackson County, the Michigan Central Railroad changed its line at an average cost of $165.67 per acre. The Jackson and Battle Creek, a new line, parallel with and adjoining the Michigan Central, paid $239.53; the Jackson and Suburban, a new electric line, paid $293.34, and the "Ypsi-Ann" Electric paid $393.74. All the new lines in Monroe County are higher than any changes of line in similar country. The Ann Arbor change in Washtenaw County, located by the writer, is at one point 3 miles from the old right of way, and only at the two ends of the 7-mile line does it run on farms owned by parties crossed by the old road; therefore, to all intents and purposes, it is a new line.

The naked land values used in 1900, being clearly too low, were of no use and were dropped. The so-called market price of right of way as given in 1900 was misleading.

TABLE 4.—Comparison of Country Land Values.

The actual purchases are averaged from recent transfers, and represent consideration paid to land owners, but not the cost of acquiring.

The 1900 appraisal averages show all country land after fixed charges and percentages were added, per rule of 1900.

County.	Railroad.	1900 Appraisal, average per acre.	Railroad.	Actual transfer, average per acre.
Jackson... ..	Michigan Central Air Line.....	$71.36	Michigan Central Air Line. New Line.....	$165.67
	Michigan Central.....	88.47	Jackson and Battle Creek. Average entire county.....	239.53
	Michigan Central. Waste land.	5.00	Jackson and Battle Creek. Waste land.....	65.79
	Michigan Central. First-class farm.....	93.30	Jackson and Battle Creek. First-class farm.....	293.51
	Jackson, Lansing and Saginaw. Average country values.....	75.72	Jackson and Suburban.....	293.34
			Detroit, Ypsilanti and Ann Arbor.....	393.74
Monroe.....	Flint and Pere Marquette.....	93.30	Flint and Pere Marquette. Monroe to Toledo.....	215.21
	Michigan Central.....	93.30	Toledo and Monroe. Electric	461.13
	Lake Shore and Michigan Southern.....	93.30	Detroit and Toledo Shore Line (Duffy).....	214.38
			Detroit and Toledo Shore Line (Burt).....	262.49
Kalamazoo..	Michigan Central.....	89.41	Michigan Central. Kalamazoo to Mattawan	236.22
Van Buren...	Michigan Central.....	66.54	Michigan Central. Kalamazoo to Mattawan.....	196.00
Cass.....	Michigan Central.....	84.97	Michigan Central. Cut-off near Pokagon.....	260.61
	Michigan Central. Waste land.	10.00	Michigan Central. Waste on cut-off.....	60.00
Genesee.....	Grand Trunk Western.....	98.10	Grand Trunk Western. Improved line.....	337.56
Genesee.....	Pere Marquette.....	80.84	Flint and Pere Marquette. Change of line.....	234.00
Montcalm....	Pere Marquette.....	29.00	Pere Marquette - Greenville-Stanton.....	135.84
Calhoun	Grand Trunk Western.....	61.44	Grand Trunk Western. Change of line west of Battle Creek.....	491.13
Calhoun	Michigan Central.....	74.38	Jackson and Battle Creek. Electric.....	218.74
Tuscola.....	Michigan Central.....	60.75	Michigan Central. Caro-Owendale.....	73.04
St. Clair.....	Pere Marquette.....	43.18	Rapid. Anchorville - Marine City	287.05
Washtenaw .	Ann Arbor.....	38.60	Ann Arbor. Change of line near Ann Arbor.....	285.50
Ionia	Pere Marquette.....	77.50	Pere Marquette. Lowell-Belding.....	112.30
Manistee	Ann Arbor.....	25.40	Ann Arbor. Change line near Harlan	47.33
Osceola	Pere Marquette.....	40.03	Pere Marquette, Change line near Evart	57.93

Having shown that there is an increase in cost of railroad over farm land, the question arises: Is it legitimate? If it is a proper item of cost, has it a place in the present value column?

In building a new railroad, engineers prepare their estimates of cost, including grading, rail and fastenings, ties, bridges, and, among other items, right of way. Their clients provide funds to build the line, and furnish, among other items, cash for the right of way. The right-of-way account in no wise differs from that of any other item of physical cost. The right of way, with all its hold-ups, items for damages, court costs, legal expenses, bills for personal services and expenses in securing it, abstracts and recording of deeds, is just as much an element of physical cost as the rails. The cost of acquiring the right of way is as proper an element as charges for inspecting the rails, freight charges on them, the loading and unloading, or any other charges that enter into the cost of rails delivered to the track-laying contractor.

Should the cost of reproduction of right of way be carried to the present-value column? Clearly, yes. If a road is unfortunate enough to buy its rails when they are at a price of $60 per ton, the full price is charged to capital account; and when the line is sold to some large corporation, no reduction is made, even though the price of rails be much less at the time, but the selling price is based on the construction account as a whole.

The same is true of the right of way. In no case which has come under the writer's notice has a new company, or a set of promoters disposing of a new line or a new right of way, ever consented to deal except on the basis of construction account, plus promoters' profit. The cost of a right of way is increased on account of continuity. A farmer is justified in increasing his price per acre by reason of the fact that the road must have a continuous line, regardless of how it affects the individual. He must rearrange his fields, replant his orchard, change his fences, ditches, and tile lines, and re-adjust his entire property to accommodate the necessity of the road. He must also take into account severance or damages. He is compelled to cross the line at an inconvenient place, open and close two gates in every lane or at every crossing, drive his cattle back and forth to water, haul his produce over a short heavy grade across the track, and he must not interfere with the railroad. He is in constant danger of loss of property from fire or from accident, and he is in personal danger every time he passes from his own land on one side of the railroad to his own land on the other side. Every one who has bought right of way knows these argu-

ments, and is aware that the farmer knows them and charges extra on account of them.

The law provides that, in condemnation, the jury shall take into account two elements, the value of the land, and damages. The railroad pays them, and very promptly charges the entire cost to the right-of-way account. No one will question the propriety of the farmer taking them into account in fixing his price. The value of continuity to the railroad can hardly be measured in dollars and cents.

A fair illustration of continuity may be found in coal lands. A promoter will secure option on a large acreage. As long as his holdings are disconnected and widely separated they are of no more value than adjoining lands, but let him close options on a large block of land all in one body, and immediately he can add from 100 to 200% to the value of his land for mining purposes. This added percentage is due to continuity.

The conditions surrounding the purchase of railway lands in Michigan have changed materially in the past few years. In a new country, without means of transportation, land values are low, and, in order to open new markets, land owners can afford to donate the right of way. Undoubtedly, a very large percentage of the total right of way on the older lines was either donated or bought at very low prices. As a community grows and develops, acquires new industries, and receives new improvements, property values increase; and, along with a general appreciation of other values, those of railroad property must increase. It would certainly be true that the present value of the site of the Majestic Building, in Detroit, is not the same as it was in 1850; the argument that its actual cost in 1850 was, say, $200, would not be any justification for such a value to-day. Equally is it true that the value of property owned by the Michigan Central Railroad is not to be measured by the price paid for it 50 years ago. The greater business, and the larger income derived from that business, make the Detroit of to-day a much more valuable terminal for the road than the Detroit of 50 years ago.

The same argument will apply to any city which has grown up after the construction of railroads. The original right of way was farm land and may have been a donation, but the change from farm to city certainly increases the value of the railroad land just in proportion as the surrounding land increases.

The same reasoning is properly applicable to lands which decrease in value. Where a railroad buys right of way to gain access to valuable timber lands, and, after the removal of the timber, the land is too poor to support a population, the present value should depreciate in the same ratio as the surrounding land, and immediately on its abandonment as a right of way it would cease to have a railroad value.

In an appraisal, it appears to be fair to base the cost of reproduction on the cost of building a new line on the location of the road under appraisal, all other means of transportation remaining as they are to-day, so as to secure as nearly as possible the conditions that would be encountered by a new company building a new line on this location.

The argument was made in 1900, and reiterated frequently, that railroad companies secure many donations. It may safely be said that, in a developed country, such as in the south half of the Lower Peninsula, the donations are of little account. Few donations were found in an examination of records of deeds covering 10 years; and in some cases the conditions were so burdensome that it may be said that the gift land was the most expensive. A condition for a cattle-pass costing from $400 to $600, a side-track costing from $1 to $1.50 per ft., and other like specifications are found; and in many deeds where a liberal consideration is named conditions which add greatly to the cost are not infrequent.

The recent new lines in Southern Michigan secured but few donations, although all considerations of $1 and other good and valuable considerations were classed as donations unless the contrary was susceptible of proof. In the case of the Ann Arbor Railroad, in Washtenaw County, the $1 consideration represents a higher price than the average, this being known by the writer, as he bought it. The same is true of the Detroit and Toledo Shore Line, in Monroe County. In making an appraisal, no deductions should be made for donations, if there are any, as the fact that land is donated does not indicate absence of value; nor should an addition be made to the appraisal value on account of the fact that a road has been held up and compelled to pay exorbitant prices in certain localities.

In some counties the base values of land in villages and small towns were given at ridiculously low prices in 1900; some are as low as from $50 to $100 per acre in towns of from 1 000 to 3 000 population. When one stops to consider that a lot 4 by 8 rods contains $\frac{1}{5}$ acre, and

that such lots in a town of considerable size range from $50 to $300 each, it is readily seen that from $250 to $1 500 per acre are not excessive figures. The figures for an adjoining county were often very high, and village values were put up to substantially full value. The result of adding percentages in 1900 was to magnify discrepancies, and little villages of from 200 to 500 population in one county were appraised at a higher rate than towns of from 2 000 to 5 000 in the next.

In 1902 the appraiser undertook to equalize all such discrepancies, and found that no hard-and-fast rule would apply. A comparison of village values, as determined by actual purchase, with the 1900 appraisal, is given in Table 5.

The 1900 appraisal for city lands, outside of Detroit and Grand Rapids, was generally very conservative or low. In some cases the figures were extremely low.

TABLE 5.—Average Price per Acre for Village Land.

Actual purchases are averaged from recent transfers. The 1900 appraisal averages are averages of prices as applied after all percentages and fixed charges are added.

County.	Name of road.	Name of village.	Appraisal, 1900. Average per acre.	Actual transfer. Average per acre.
Jackson	Michigan Central	Parma	$177.25	$1 166.65
Van Buren	Michigan Central	Mattawan	571.00	2 439.04
Tuscola	Michigan Central	Caro	571.00	733.42
Oakland	Pere Marquette	Clyde	346.00	333.00
Oakland	Pere Marquette	Milford	571.00	1 136.37
Genesee	Pere Marquette	Grand Blanc	121.00	327.87
Kent	Pere Marquette	Lowell	571.00	1 552.26
Ionia	Pere Marquette	Belding	1 000.00	967.77
Washtenaw	Michigan Central	Dexter	571.00	718.75
Washtenaw	Michigan Central	Delphi	233.50	2 383.34
Cass	Grand Trunk Western	Cassopolis	458.50	1 600.00
Cass	Grand Trunk Western	Edwardsburg	222.25	466.67

The conclusion reached by the appraiser in 1902 was that, for railroad purposes, right of way is worth what it costs to produce it. It would be just as consistent to claim that a railroad has a misfortune in having a river to cross, and that no value should be placed on the bridge which spans it, as to claim that right of way, which costs three times farm-land values, should not be valued at a higher figure than farm land.

TABLE 6.—Comparison of Valuation Figures with Actual Considerations.—Comparison of Immediately Adjoining Properties, Grand Rapids, Michigan.

The prices are per square foot or per acre.

Location.	Size of lots.	Michigan Central appraisal.	Pere Marquette appraisal.	Actual transfer.
Fulton to Island Street.	50 by 100 ft.	.....	$2.00 per sq. ft.	$1.40
Island to Oakes Street..	50 by 100 ft.	.....	2.00 " " "	1.22
Oakes to Cherry Street.	.....	.....	2.00 " " "	1.33
Cherry Street Frontage.	130 ft. deep	$1.23 per sq. ft.	1.23 " " "	.....
Cherry to Williams Street.....	50 by 130 ft.	.....	.....	1.55
Williams Street Frontage.....	130 ft. deep	0.92 " " "	0.54 " " "	.....
Williams to Bartlett Street.....	.....	.....	.....	0.76
Bartlett Street Frontage.....	130 ft. deep	0.77 " " "	0.46 " " "	.....
Bartlett to Goodrich Street.....	.....	.....	.....	0.62½
Goodrich Street Frontage.....	130 ft. deep	0.62 " " "	0.38 " " "	.....
Goodrich Street to Wealthy Avenue.....	.....	.....	.....	0.39½
Prescott to First Street.	.....	0.25 " " "	.....	0.54
First to Second Street..	.....	0.25 " " "	.....	0.16
Land on Hall Street....	....	1 500 per acre.	1 359 per acre.	3.75
North side of Hall Street	.....	.....	1 000 " "	.....
Hall to Stevens Street..	....	1 500 " "	800 " "	1 351.11 per acre.
On Crofton Street.....	.....	400 " "	....	400.00 " "

The problem of an appraiser is to determine, with the best evidence at hand, what land is fairly worth for railroad purposes at the time of appraisal. He must take into account the railway-purpose increment, if he is consistent in his appraisal.

Non-Physical Values.

The foregoing narrative account of the general field and office handling of the Michigan appraisal of physical property, while not touching on matters of principle of valuation, except as to land values, is submitted as describing briefly the machinery of the appraisal. A number of very important issues were raised which have to do with the theory of valuation. These are worthy of discussion at length, in the subsequent consideration of the method of determination of a fair value, but are not here referred to. Within any short limits it is impossible to give a comprehensive description in detail of all the work of the Michigan appraisal. Several articles descriptive of this work have been written, giving quite full extracts from the

various sets of rules which were promulgated, and describing some phases of the work in much more detail than is here attempted.

The physical valuation, as represented by two figures—the cost of reproduction of the physical property, and its present value—was submitted to the Board of State Tax Commissioners as the work of Professor Cooley, and in most of the literature descriptive of it, it has been termed the "Cooley Appraisal."

After the completion of Professor Cooley's work, his figures were submitted to Professor Henry C. Adams, who had been making a study of the income accounts of the various companies, and to whom had been assigned the duty of determining the non-physical or franchise values of the properties.

Professor Adams has described* very fully the plan adopted for this work, and this plan has been commented on so fully that any lengthy description is deemed unnecessary. It appears to be perfectly proper, however, to correct certain misstatements regarding this work.

When it was first determined to make the appraisal, Professor Cooley—not Professor Adams—was requested to take charge. The assignment to Professor Adams of the non-physical valuation was made after the physical valuation was well under way.

The use of a negative or subtractive non-physical value was considered, and advised by Professor Adams. The work was not undertaken with a view of "increasing the assessments," but to put the Tax Commission in possession of a figure which would represent the business value of the property as well as the physical value.

Professor Adams held that the non-physical element of value was not a simple commercial element, but included:

The franchise { to be a corporation,
to use public property,
The possession of traffic not exposed to competition,
The possession of traffic through connections,
The benefit of economies due to density of traffic,
The value due to organization and vitality of industries served.

He also held that, as nothing visible or tangible gave support to this value, it must be determined on the basis of information secured from the income accounts of the company.

* Bulletin 21, U. S. Bureau of the Census, p. 78.

Without going into any complete description of Professor Adams' method, it may be said that he made an analysis of the income accounts, and, after providing for operating expenses and taxes, he deducted, as an annuity properly chargeable to capital, a certain percentage of the appraised value of the physical properties. Any remainder was capitalized to give the true value of the immaterial element, or the business value.

In the rates of capitalization and annuity used in 1902, there were certain changes, making them differ from those used in 1900, and certain changes in the detail of analysis of income accounts and methods of determining the rates of interest which are entirely immaterial to the present narrative. The work was of great importance as being the first exposition of this method of obtaining non-physical values. It was a fair, logical, and business-like attempt to determine those elements which give a well-designed, economically-built, or advantageously-located property a greater value as a money-earning concern than the actual capital invested, or than the actual value remaining in its physical property.

It will be seen that, in the case of a property in which the surplus earnings depend on excessive rates for service, it will fail as a method of determining a value for use as a basis of rate-making; and it fails, in the form in which it was used in 1900 and 1902, to bring out those negative or subtractive elements which may be determined from the income accounts, in the case of properties which do not earn a fair return on the investment. This, however, was due to the fact that the taxation laws of Michigan made no provision for any reduction of value because property was idle or non-productive, and any such deduction in the case of corporation property would place it on a different basis from other property. Professor Adams and his associates, therefore, applied only positive values, where any such were found, although advocating the use of negative values.

The writer has seen no criticism of Professor Adams' work which is not apparently incited by, either the direct interest of corporations in lowering valuations for taxation, or by an effort to confuse the subject of valuation so as to discredit the work in the eyes of taxing authorities. Any person competent to discuss the matter, who has given Professor Adams' method careful thought, will be forced to the conclusion that this was a long step in the direction of the final solution of these important and perplexing elements of value.

History and Results of the Michigan Appraisal.

Based on the valuation of 1900, the Board of State Tax Commissioners was enabled to comply with the statute in reporting to the Legislature. New laws were passed, sundry suits were brought, and, finally, the case of the Michigan Central Railroad *vs.* Perry F. Powers, Auditor-General, and a number of other cases in behalf of other roads, were brought to trial before the United States Court for the Western District of Michigan.

This Michigan Central case was a suit to restrain the collection of taxes based on the new assessment, the railroads claiming that their property was assessed at full value, while general properties of the State were assessed at a considerably lower percentage than full value. This suit was essentially a valuation of the railroad properties as of April, 1902. This work was done along the same line as the former valuation, by a portion of the same staff. The old work was brought down to date, and certain special studies were made, which resulted in a change of right-of-way valuation, as has been related.

In the trial of the case of Michigan Central Railroad *vs.* Powers, the two valuations were fully testified to by all the men engaged, and the record relative to the appraisal fills several volumes.

Subsequently, in 1906, Professor Cooley was engaged by the Attorney-General, and, re-assembling the staff, brought the work down to date as of April, 1906.

There has been no permanent force engaged on the work in Michigan, and the re-appraisals have only been made as actual necessity demanded.

Market Value of Stocks and Bonds.—During the progress of the appraisal of 1900 an independent force of men was engaged in studying the market values of stocks and bonds of Michigan roads with a view to securing information on every possible line that would aid the appraiser in reaching proper conclusions, or enable him to check his figures. These figures were used only as a check, and no report of the details of this work was submitted.

Error in Published Reports as to Michigan Work.—In several articles descriptive of the Michigan work, one quite serious misstatement of fact has inadvertently been made. The writer is not quite sure how or where the wrong impression originated, but it has been noted in several articles and editorials.

Substantially, all accounts are similar to that of Professor Taylor,* which is:

"In looking over the notes and results of the work done in Michigan, it was noticed that Mr. Cooley's engineers, car-men and other experts went over the property of each railway company and enumerated and valued the same, and then the railway company generally had its own men perform the same work in order to check up the appraisal made by the State authorities. Thus, this expensive work was unnecessarily duplicated."

Undoubtedly this statement was made in good faith, and has gained currency by not having been corrected, but it is not the fact.

The Chicago and Northwestern Railway took immediate steps to make surveys and secure data, as has been described, and made a complete appraisal, using the Michigan forms. The result of this appraisal was:

Chicago and Northwestern, present value.....	$8 551 530
State appraisal, present value.....	8 281 090

In this case the railroad had no records, and the work was of value to them, not only as a check on the work of the State, but also as giving them complete records of permanent way. It was not done independently of, and after, the State work, but was organized so that the field work of both railroad company and State was done at the same time.

No other complete work of valuation was done by the railroad companies. During the trial of the cases, no contrary or different valuations were set up. No special attack was made on the work, except to select here and there some specific example of a building which was appraised at a higher figure than cost, perhaps half a dozen in all, and to introduce expert evidence, particularly on land and right-of-way values. Aside from the money expended on the litigation, there were no expenditures by the roads in checking up the work. On the contrary, a number of managers, at their own expense, had typewritten copies of the final report as to their own lines made, in order to file in their records.

It is a fact that only one of the seventy-eight roads made a complete appraisal, covering 387.8 miles of main line, and none of the other roads or mileage went to any considerable expense.

* Bulletin 21, U. S. Bureau of the Census.

The Cost of the Work.—No complete statement of the total cost of the work of valuation in Michigan has ever been issued as a public document. The cost of the work, including salaries of appraiser, engineers, assistants, clerks, all expenses of the Board of Review, all expenses connected with Professor Adams' non-physical appraisal, also all office rent, stationery, supplies, telegraph, telephone, and railroad expenses, printing and binding—in short every dollar chargeable to the Michigan railroad appraisal of 1900—footed up to $70 604.21.

The exact mileage of roads in the State was:

Main track	7 082.35	miles.
Second track	164.83	"
Branches	730.92	"
Spurs and sidings	2 904.70	"
Total	10 882.80	miles.
Average cost per main-line mile	$9.97	
" " " total-track "	6.50	

The exact figures of cost of the subsequent work of appraisal, or the costs of the litigation, are not available to the writer. In a general way, it may be said that the cost to the State of the railroad tax cases was not far from $75 000, and that the expenses of the second and third appraisals were less than $50 000, so that, to date, the entire cost to the State of Michigan is less than $200 000 for the three appraisals and the litigation growing out of them.

Some information as to details of costs may not be out of place. All employees were paid a salary and required to provide their own subsistence. Salaries ranged from $250 to $500 per month for experienced men, from $125 to $250 for men with only a few years of experience, and from $75 to $125 for assistants and clerks.

All traveling expenses (except hotel and subsistence) were paid, the State issuing mileage books to all employees, and receiving a complete check on the movements of every man through the mileage bureau. The telegraph and long-distance telephone were used almost exclusively in communication between the office and the men in the field, all bills being paid by the State. All expenses of inspection by hand-car, velocipede-car, etc., were paid by the State, except as the roadmasters made trips with the inspectors.

The unvarying policy of the appraiser was to reimburse the companies for all extra expenses incurred on account of the work, and to accept no transportation or favors from any company.

TABLE 7.—GRAND SUMMARY OF RAILROAD APPRAISAL OF 1900 AS TO SEVENTY-EIGHT INCORPORATED RAILROADS.

PHYSICAL APPRAISAL.

Item No.	Subject.	Cost of reproduction.	Present value.
1	Engineering, 4% on items 2 to 25, inclusive, and on item 33	$5 386 772	$5 386 772
2	Right of way and station grounds	27 745 313	27 745 313
3	Real estate	863 337	863 337
4	Grading	21 699 995	21 693 024
5	Tunnels	1 148 070	1 093 445
6	Bridges, trestles, and culverts	8 027 119	6 337 819
7	Ties (cross- and switch-ties)	11 139 924	6 148 748
8	Rails	28 703 012	21 865 994
9	Track fastenings	3 845 030	2 987 982
10	Frogs, switches, and crossings	1 469 781	1 040 120
11	Ballast	3 723 558	3 723 558
12	Track laying and surfacing	6 555 638	6 400 972
13	Fencing	2 763 595	1 627 790
14	Crossings, cattle guards, and signs	607 542	428 474
15	Interlocking and signal apparatus	501 883	448 686
16	Telegraph (30) telephones	258 985	134 797
17	Station buildings and fixtures	4 108 736	3 111 103
18	Shops, round-houses, and turn-tables	2 157 228	1 467 569
19	Shop machinery and tools	1 107 910	882 634
20	Water stations	725 670	522 135
21	Fuel stations	303 289	201 461
22	Grain elevators	1 336 794	1 609 043
23	Warehouses	258 646	188 910
24	Docks and wharfs	5 531 919	3 831 984
25	Miscellaneous structures	1 234 345	856 253
26	Locomotives	9 021 517	5 092 053
27	Passenger equipment	3 197 473	2 277 271
28	Freight equipment	19 734 240	13 690 587
29	Miscellaneous equipment	702 940	423 689
31	Ferries and steamships	1 725 000	1 095 500
32	Electric plants	93 061	89 898
33	Terminals. Included in Items 1 to 32.		
34	Legal expenses, 0.5% on items 2 to 25, inclusive, and on item 33	673 349	673 349
35	Interest, 3% on items 1 to 34, inclusive	5 290 549	5 290 549
36	Miscellaneous expenses... Organization, 1.5% on items 1 to 34, inclusive	2 645 277	2 645 277
	Miscellaneous expenses... Contingencies, 10% on items 1 to 34, inclusive	18 428 753	15 127 110
	TOTAL COST OF CONSTRUCTION AND EQUIPMENT	$202 716 262	$166 398 156
37	Stores and supplies	1 474 829	1 474 829
	Average per main-line mile	28 263	23 495
	" " total-track mile	18 627	15 290
	TOTAL VALUE OF NON-PHYSICAL ELEMENT (H. C. ADAMS)	.....	35 814 043

The Result of the Michigan Work.—Any undertaking must be judged by its results. The Attorney-General's report for 1906, on pages 21 and 23, states:

"These cases are among the most important in the history of the State. They constitute the last step in subjecting railroad property in Michigan to taxation on the same basis and at the same rate as other property is taxed, and secure practical uniformity and equality of taxation between railroad and other property.

"As a result of these cases the various railroad corporations paid in taxes $4 787 478.15, and as penalty thereon $1 158 321.18, a total amount of $5 945 799.43 for the years 1902, 1903 and 1904. The 1905 tax being paid soon after the decision of the Supreme Court, nothing was paid under the former law (specific tax on earnings) and, of course, there was no penalty on the 1905 taxes as they were paid before May 1, 1906."

In short, the roads are paying to the State of Michigan an average of $1 595 826.05 more per year than they paid under the old law, and to date the State has received about $10 750 000 more from taxes than it would have received under the old specific tax law.

Railroad development in Michigan has received no appreciable check, and notwithstanding a 2-cent fare and the bearing of an equal burden of taxation, the properties are maintained, and improvements, double-tracking and betterment of general standards fully keep pace with similar work in other States.

Of course, it must be recognized that other forces besides the appraisal helped to bring this about. The appraisal of 1900 furnished the information. Public opinion compelled the passage of the needed laws, and the magnificent legal work of Attorneys-General Blair and Bird, Congressman Townsend, and Judge Knappen, and their associates, loyally supported by Professors Cooley and Adams and the appraisal staff, were all factors in securing the decision of the Supreme Court of the United States.

Railroad Appraisal of the State of Texas.

Authority for the Work.—In 1893 the Legislature of Texas enacted what is known as the Stock and Bond Law, which was designed to control and limit the total amount of stocks and bonds that may be issued on any railroad property to the "reasonable value of said railroad property." This law further provides that:

"It shall be the duty of the Railroad Commission to ascertain, and in writing report to the Secretary of State, the value of each railroad in this State including all its franchises, appurtenances and property."

The work of valuation in Texas antedates that in Michigan, and offers some interesting opportunities for comparison of methods under somewhat similar conditions, as far as the existing roads were concerned. The work being in the hands of a permanent commission with very broad powers, it has been possible to secure from recently built roads very full and specific data as to construction, but with these later valuations and with the current work of the department, this paper will not deal.

The Commission of Texas interpreted the law to mean the estimated cost of reproducing or duplicating the properties at the date of valuation, allowing current market prices for all material and fair valuations on all real property.

Method of Physical Appraisal.—The Commission duly appointed engineers to make these valuations. The railroads of the State were unfavorably disposed toward the work, and were inclined to withhold information.

The Texas staff encountered the difficulty due to destruction or loss of construction records, maps, and profiles. They had for their guidance only the profiles, filed under a prior law, and were thus compelled to depend wholly on original field work to secure their data. From a paper by R. A. Thompson, M. Am. Soc. C. E.,* the following description is taken:

"They [the engineers] with the profiles * * * in hand, made a detailed inspection of the railroads on the ground. The quantities of excavation and embankment, where the actual quantities could not be obtained, were estimated approximately from the profiles, using the center heights of the cross-sections. The classification of the materials in excavation was determined by inspection. Where original plans and estimates of cost of the bridges, buildings and structures of all kinds could not be obtained from the records of the railroads, their value was estimated from measurements taken on the ground. The extent and acreage of the right of way, the depot and terminal grounds, were determined by actual measurement, or from maps furnished by railroads, or from city and county tax records.

"After an examination of a railroad had been made by the engineers of the Commission, its valuation was prepared on estimate sheets. Upon sheets marked Estimate Sheet A * * * were recorded the values of the right of way and depot grounds, roadbed, track, bridges, structures and way building for each mile, the value of ten miles being

* *Transactions*, Am. Soc. C. E., Vol. LII, p. 328.

recorded on each sheet. * * * On these sheets space was provided for the units and prices, and columns for carrying out the values for each mile and the totals.

"The value of all rolling stock and equipment, and the value of such properties as were properly applicable and chargeable to the entire railroad, were recorded on a separate estimate sheet, only one sheet being used for a railroad."

It thus appears that the general methods of securing the data and making the field examination were quite similar to those adopted on the Michigan work. The classification of items on the sheets is rather more full than on the Michigan summary sheets, but apparently not so completely in detail as the final compilation of work. In general, however, the physical items included are complete in both cases. The form in which the results are finally put up is radically different.

The following points of variations from the practices of the Michigan appraisal are noted:

(*a*) The unit prices were current market prices.

(*b*) The value applied to right of way and real estate used for railway purposes was in accordance with the current market value of other property immediately adjoining, disregarding donations or property acquired at less than value.

(*c*) No deduction was made on account of depreciation, as it was considered that all structures must be maintained in first-class, serviceable value, and renewed when necessary, and no allowance was made for appreciation of roadbed.

(*d*) No allowance was made for franchise values of any kind, except track rights in streets.

(*e*) No allowance was made for contingencies, except as made in prices or quantities.

Their practice was in accord with the Michigan appraisal, in allowing from 5 to 6% to cover legal and engineering expenses and superintendence, and from 5 to 6% to cover interest during construction.

The Result of the Texas Work.—The object sought in Texas was to secure a capitalization in harmony with the actual investment in the physical property; in short, to "squeeze out water."

Of course, all stock and bond issues outstanding in 1894 are still in existence, except as a few roads have been sold out or re-or-

ganized. No new issues of stock or bonds may be made on roads in excess of the valuation. Consequently, new roads are limited to issues of bonds not far from $15 000 per mile. The effect is shown by Table 8, from the Railroad Commission's Report.

TABLE 8.—MILES OF RAILWAY IN OPERATION IN TEXAS, 1894 TO 1908, WITH OUTSTANDING STOCKS AND BONDS.

On June 30th.	Miles of railway in operation.	Stocks outstanding, per mile.	Bonds outstanding, per mile.	Total stock and bonds outstanding, per mile.
1894	9 154	$15 076	$25 726	$40 802
1895	9 291	14 874	25 420	40 294
1896	9 437	14 647	25 302	39 949
1897	9 484	14 320	24 793	39 113
1898	9 540	14 205	24 036	38 241
1899	9 702	13 997	23 562	37 559
1900	9 867	13 724	23 202	36 926
1901	10 154	12 922	22 649	35 571
1902	10 617	12 388	21 779	34 167
1903	11 029	11 971	21 464	33 435
1904	11 495	.....	.....	32 400
1905	11 662	.....	.....	33 418
1906	12 056	.....	.....	32 886
1907	12 577	.....	.....	32 142
1908	12 830	.....	.....	32 305

Total reduction, up to 1903, of stock per mile.....	$3 105
" " " " " " bonds " "	4 262
Total stock and bonds....	$7 367

E. L. Corthell, M. Am. Soc. C. E., speaking of results secured by the Texas law, says*:

"The law, and generally its just operation, has cured many unmitigated and notorious evils. Not only has the public in Texas been benefited, but also the investor in railroad securities from the outside of the State. The people of Texas now have just and uniform rates of transportation, and the investor knows what he is purchasing, and may be reasonably sure of a return on his investment."

Mr. Thompson says†:

"Another significant fact is that only a short time before the Stock and Bond Law became effective about 39% of the railroads in Texas were in the hands of receivers. To-day there is not a mile, of the 11 300 miles in Texas, in the hands of receivers, and, with a few unimportant exceptions, no railroad has been in the hands of receivers since the law went into effect. The fact is that there has been no piece of legislation, in this or any other State of the Union during the past decade, which has been so fruitful of results and beneficent in its action, alike to the railroads and the people."

* *Transactions*, Am. Soc. C. E., Vol. LII, p. 346.

† *Ibid.*, p. 364.

Railroad Appraisal of the State of Wisconsin.

The State of Wisconsin made a valuation of railroad properties of the State as of June 30th, 1903, the work being under the direction of W. D. Taylor, M. Am. Soc. C. E. The plan adopted, the methods of work, and the general result of independent studies conducted by Professor Taylor have been described so fully in various technical papers and reports elsewhere listed, that a very brief statement of points of difference between the Michigan and Wisconsin works appears to be all that is necessary here.

Professor Taylor associated with him for consultation Professor Cooley, of Michigan, made a careful study of methods used in earlier appraisals, used the Michigan blank forms as a basis for the preparation of his own, and thoroughly outlined his general plan and the scope of the information desired before actually organizing his staff or commencing work.

In connection with the earlier stages of the work, conferences were held with the officials of the principal railways of the State, and developed a thorough understanding and plans for co-operation between the appraiser and the roads. As a result of these conferences, each large railway company of the State, acting through its heads of departments, made an inventory and appraisal of its own property in the State, using therefor the forms and blanks prepared by the appraiser. At the same time, the appraiser organized a considerably smaller force than was used in Michigan, made his own office and field inspection, and secured data to complete the appraisal on the small roads, in which their own engineering or operating departments were not organized so as to do the work according to plan.

The work turned out by the large roads was then checked by this force, the various points in which they were out of harmony were checked and unified, a number of hearings were held, certain portions of the work were checked over by the appraisers' men, sundry changes in quantity and price were made, and finally, when the work was compiled and put in shape for presentation, the appraiser had reason to believe that he had secured a result which was reasonably free from error, and one in which the railroads had co-operated to such an extent that no charge of prejudice or unfairness would lie.

It is noted that the average cost of reproduction and the present value per mile in Wisconsin are higher than in Michigan, which

is probably as it should be, as Michigan has a less mileage of high-class main trunk line road than Wisconsin.

In general, the two appraisals were very similar. The determination of unit prices, the placing of depreciation, the apportionment of locomotives, freight, and passenger equipment, and other rolling stock, the use of the Interstate Commerce Commission's construction classification, the application of percentage values for engineering, interest during construction, administration, legal expenses, and contingencies (this latter fixed at 5.5%), all were along lines similar to those developed in Michigan.

The work of the Wisconsin appraisal was carried on at the same time as the second Michigan appraisal. The investigations made by Mr. Van Ranst Pond and the writer, as to the actual sale prices of right of way, fully discussed heretofore, were conducted at the same time as Professor Taylor's work in Wisconsin was being done, and neither party had any knowledge of the work of the other. The prior discussion relative to this phase of the Michigan valuation is practically a revision of a memorandum submitted by the writer to the Attorney-General in January, 1904. The tables are abstracted from much more extensive ones which, supported by the evidence of Registers of Deeds of some ten counties of Michigan, are part of the record of evidence in Michigan Central Railroad *vs.* Powers. It is, therefore, not only of great interest, but great value, as supporting Professor Cooley's right-of-way valuations, to note the following extract* from Professor Taylor's discussion of the paper by Mr. R. A. Thompson on the Texas railroad valuations:

"In the Wisconsin appraisal, the method followed for valuing the right of way and terminal lands was about as given below. Parts of the right of way of some of the larger systems are estimated at higher ratios than this, but in such cases the roads themselves fixed the right-of-way value.

"The market value for other purposes of the right of way and terminal lands was judged to be the same as that of contiguous property.

"In farming lands, small towns, and suburban and residence property, the right-of-way value was taken to be 250% of the market value for other purposes.

"In city property, the right-of-way value was taken to be 133% of the market value for other purposes, where the land was owned

Transactions, Am. Soc. C. E., Vol. LII, p. 359.

in strips of 100 ft. width or less, and 110% of the market value for other purposes, where the land was owned in blocks, or in widths greater than 100 ft."

No effort whatever was made in the Wisconsin valuation to determine any non-physical or intangible values, the report covering only cost of reproduction and present value of the physical properties.

The Wisconsin work is noteworthy as the first appraisal in which the hearty co-operation of the railroads was secured from the outset. In Michigan the roads at the inception viewed the work with distrust, but by the completion were in hearty sympathy with the efforts of the appraiser to use just and honorable methods, and the managements extended every courtesy in the way of access to records for verification purposes.

The Minnesota State Railway Appraisal.

The valuation of railway properties in the State of Minnesota was undertaken with a view to establishing a basis for rate-making. The work was in charge of Mr. Dwight C. Morgan, Engineer of the Railroad and Warehouse Commission of the State, whose full and complete report is a very valuable addition to the literature of valuation practice. This work was undertaken after the completion of that in Michigan and Wisconsin, and advantage was taken of the experiences of the appraisers in these two States. The Wisconsin plan of co-operation with the railroads was adopted, and each company scheduled and appraised its own lines.

The "cost of reproduction," and "present value of physical properties" were the two sets of figures shown in the final results.

Unit prices were fixed on the basis of current prices in 1905, in preference to an average of 5 or 10 years.

Apportionment of locomotives and rolling stock was made on an engine- and car-mileage basis. The organization of an office force was undertaken, and special study was made of the subjects of unit prices and the various local conditions surrounding the different properties, checking of quantities of earthwork, rails, etc., and preparing to harmonize and unify the estimates as they should be received from the railroads.

The greatest difference between this work and that in the other States was the fact that the field inspection, instead of being made by many men, was made by Appraiser Morgan, accompanied by

two assistants, inspection being made in a special train, which was paid for by the State.

The detailed reports of the railroad companies were completed and in the hands of the appraiser, maps and profiles of the road were prepared and available, the train was run at slow speed, and many stops were made for examination of bridges, culverts, and structures. About 100 miles per day were covered, but this did not include the larger terminals of St. Paul, Minneapolis, and Duluth, which were given many days.

In the preparation of final summaries, percentage values were placed as follows:

Engineering, superintendence, and legal....	4½ per cent.
Contingencies.....	5 " "
Interest, time of construction varying according to mileage from 1 to 8 years.....	4 " "

In addition to these three items, the item of "adaptation and solidification of roadbed" was given a large place, being, for all the roads of the State, $11 743 007.15. This feature was novel to this class of valuation, and it is to be regretted that, in his report, the appraiser did not narrate more fully the detailed methods by which he arrived at his resultant figure.

Land Valuation.—The vexed question of a proper value to give to lands owned by a railway company, was treated by Appraiser Morgan in a different way than it had been in Wisconsin or Michigan. A number of special agents were appointed, who made an exhaustive study of the transfers and assessed values throughout the State. The discussion of this subject in Mr. Morgan's report is exhaustive, and of great interest. The conclusions are quoted. It is regretted that the discussion of methods of valuation can only be given in brief form.

"Careful and full consideration of all information made available for establishing the value of the right of way owned and used by the railway companies for railway purposes, led to the conclusion that in the state at large exclusive of the three terminals of St. Paul, Minneapolis and Duluth, a multiple of three (3) applied to the true value or normal value of lands, as obtained from the transfers, would in general satisfy the conditions.

"During the period referred to, the railway companies paid for the property acquired by them, over and above its normal value, an amount sufficient to justify the use of the following multiples: St. Paul, one

and three-fourths (1¾); Minneapolis, one and three-fifths (1⅗), and Duluth, one and one-fourth (1¼), which when applied to the normal value of the lands as established from contiguous and surrounding property, formed the basis for measuring the cost of reproducing the existing terminals of the railway companies."

In the final compilation of results, two sets of schedules were rendered:

(*a*) Those which gave the land values with added increment,

(*b*) Those which omitted the increment.

The cost of the engineering work was about $70 000; this covered 7 596.4 miles of main track, 427.4 miles of second track, and 2 414 miles of side-track, or a total of 10 437.8 miles of all tracks. As yet there has been no decision by the Courts on the Minnesota rate cases.

Forms Used in the Compilation of Information.—The forms used in the Michigan appraisal have been described and fully illustrated. They were all printed on 8½ by 11-in. sheets.

The Wisconsin appraisal used the Michigan forms as a basis, twenty of them being practically identical with the corresponding Michigan forms. The forms shown by Figs. 11 to 21 are materially different from those used in Michigan.

The forms used in Minnesota in 1906 were based on those of Michigan and Wisconsin, and were printed on 14 by 18½-in. sheets. They were remodeled and elaborated to such an extent, however, that the writer believes himself justified in submitting reproductions of the entire set, as representing the most complete form for inventory yet used on any of the State appraisals.

The appraiser in Nebraska in 1909, and Mr. Hansel in New Jersey in 1910, have both returned to the 8½ by 11-in. sheets, and, while both clearly followed earlier precedent in general, both have modified the details to suit the requirements in their respective States.

The Washington State Appraisal.

The State of Washington, through its Railroad Commissioners, made an appraisal of railroad properties within its borders, the work being under the direction of Halbert P. Gillette, M. Am. Soc. C. E.

From Mr. Gillette's report,* supplemented by information furnished by Henry L. Gray, Assoc. M. Am. Soc. C. E., Engineer of the

* *Engineering-Contracting.*

W.B.A. Form 1

WISCONSIN RAILROAD APPRAISAL OF 190____

ROADBED REPORT

PART I

Name of Road_____

Between_____and_____

_____ Office Inspector

_____ Field Inspector

Date_____190____

	LOCATION	ACRES	TOTAL EXCAVATION AND EMBANKMENT			TIES			BALLAST		RAILS		
		Clearing and Grubbing	Earth, cu. yds.	Loose Rock, cu. yds.	Solid Rock, cu. yds.	Number	Kind	Condition	Kind and Amount	Condition	Length of Single Track in ft.	Weight	Condition

W.B.A. Form 2

WISCONSIN RAILROAD APPRAISAL OF 190____

ROADBED REPORT

PART II

Name of Road_____

Between_____and_____

_____ Office Inspector

_____ Field Inspector

Date_____190____

	LOCATION	TIE PLATES AND BRACES			FASTENINGS			FROGS AND SWITCHES			R.R. CROSSINGS		
		Number	Kind	Condition	Number	Weight per foot	Condition	Number	Kind	Condition	Number	Rail Weight	Condition

W.B.A. Form 6

WISCONSIN RAILROAD APPRAISAL OF 190____

SIGNAL APPARATUS

Name of Road_____

Between_____and_____

_____ Office Inspector

_____ Field Inspector

Date_____190____

	LOCATION	NAME AND DESCRIPTION	No. Miles Single Line	Cost New	Condition Per Cent	

W.B.A. Form 8

WISCONSIN RAILROAD APPRAISAL OF 190____

MISCELLANEOUS ROADWAY ITEMS

Name of Road_____

Between_____and_____

_____ Office Inspector

_____ Field Inspector

Date_____190____

	LOCATION	Sets Section Tools, Hand Cars, etc.	Condition Per Cent	CROSSING PROTECTION			
				Kind	Amount	Condition Per Cent	

FIG. 11.

WISCONSIN RAILROAD APPRAISAL OF 190____ W.B.A. Form 9

Name of Road_____ Between_____ and_____

TELEGRAPH, INSTRUMENTS AND STATION EQUIPMENT

_____ *Office Inspector*

_____ *Field Inspector*

Date_____ 190____

	OWNER	LINE BETWEEN	KEYS	SOUNDERS	RELAYS			Repeaters	Cut Outs		SWITCH BOARDS			Number of Battery Cells	Make of Battery	Length Telegraph or Telephone Lines	Condition Per Cent	
					Western Union	Box	Key on base				Number of Straps	Number of Boards						

WISCONSIN RAILROAD APPRAISAL OF 190____ W.B.A. Form 38

Name of Road_____ Between_____ and_____

FENCES, CATTLE GUARDS AND HIGHWAY CROSSINGS

_____ *Office Inspector*

_____ *Field Inspector*

Date_____ 190____

	LOCATION	Wire or Wooden Fence	Length of Fence (Single Line)	No. Posts Per Mile	Size of Posts	No. Plank or Wire Per Mile	Size of Plank or Wire	Condition Per Cent	Kind of Cattle Guard	Condition Per Cent	Ft. B.M. Crossing Plank	Condition Per Cent

WISCONSIN RAILROAD APPRAISAL OF 190____ W.B.A. Form 42

Name of Road_____ Between_____ and_____

TIMBER TRESTLES AND OPENINGS

_____ *Office Inspector*

_____ *Field Inspector*

Date_____ 190____

	LOCATION	DESCRIPTION Total Length; Pile or Frame; Number Stringers; B.M. Framing; Per Lin. Ft., Etc.	Average Height Top Ground To Base Rail	No. Piles Per Bent	Average Penetration of Piles	Condition Per Cent	

FIG. 12.

Form 21
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

*Name of Operating Company*_____
*Section Number*____ *From*____ *To*____

DOCKS AND WHARVES

With or Without Coal or Ore Handling Equipment

Field Inspector
Office Compiler

LOCATION	DOCKS AND WHARVES: Item	Dimensions	Piles Lineal Feet	Framing B.M. Feet	Platform B.M. Feet	Masonry Cubic Yards	Concrete Cubic Yards	Filling Cubic Yards: Earth	Filling Cubic Yards: Stone	Age	Condition Per Cent	SUPERSTRUCTURE FOR HANDLING COAL OR ORE: Type	Dimensions	Timber B.M. Feet	Number of Pockets	Capacity of Pockets	Number of Hoists	Age	COMPLETE PLANT: Cost of Reproduction	Average Condition Per Cent

Form 22
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

*Name of Operating Company*_____
*Section Number*____ *From*____ *To*____

INTERLOCKING PLANTS

Field Inspector
Office Compiler

LOCATION	Name of Railway Crossed	When Built	TOWER HOUSE: Kind	Dimensions	Cond. Per Ct.	Kind of Machine	NUMBER OF LEVERS: Work	Spare	Total	KIND OF CONNECTION PIPE OR WIRE TO: Derails	Switches	Signals	Foundations, Wood or Concrete	SIGNAL POSTS: High	Dwarf	NUMBER OF FUNCTIONS OPERATED: Derails	Switches	Signals	ELECTRIC CIRCUIT FOR: Locks	Indicators	Bells	Average Condition Per Cent	Per Cent of Construction Cost Paid By This Company	Per Cent of Maintenance Cost Paid By This Company	Per Cent of Operating Cost Paid By This Company	Cost of Reproduction

Form 23
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

*Name of Operating Company*_____
*Section Number*____ *From*____ *To*____

SIGNAL APPARATUS

Field Inspector
Office Compiler

LOCATION	TRAIN ORDER AND MANUAL BLOCK SIGNALS OPERATED IN CONJUNCTION WITH THE TELEGRAPH: Type of Signal	Manufactured by	Number Installed	Condition Per Cent	Miles of Single Line Protected	AUTOMATIC BLOCK SIGNALS: Type of Signal	Manufactured by	Number Installed	Number Switch Indicators	Circuit Track or Wire	Miles of Single Line Protected	Condition Per Cent	DISTANT SWITCH SIGNALS: Type of Signal	Number Installed	Condition Per Cent	ELECTRIC BELLS FOR HIGHWAY CROSSING PROTECTION: Location	Manufactured by	Number Installed	Circuit Track or Wire	Condition Per Cent

Form 24
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

*Name of Operating Company*_____
*Section Number*____ *From*____ *To*____

TELEGRAPH, TELEPHONE LINES & APPURTENANCES

In Case Lines are not Owned, Only Show Such Equipment as Actually Belongs to the Railroad Company

Field Inspector
Office Compiler

LOCATION	OWNER	GENERAL DESCRIPTION: Number of Miles	Number of Poles per Mile	Number of Wires Strung	Kind of Wire	Number of Keys	Number of Sounders	Number of Relays	Number and Capacity of Switch Boards	Number of Telephone Transmitters and Receivers	Kind of Battery	Number of Cells	Cost of Reproduction	Condition Per Cent	REMARKS

FIG. 13.

Form 25
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company_____
Locomotive in Service in Minnesota_____Total Number

Field Inspector
Office Compiler

LOCOMOTIVES

Name of Builder	ENGINES																TENDER					
	Engine Number	Class	Simple or Compound	Service	Dimensions of Cylinders	Diam. of Boiler	Working Pressure	Driving Wheels No.	Driving Wheels Diam.	Weight on Driving Wheels	Weight on Trailing Wheels	Weight on Truck	Hauling Capacity	Brake Equipment	When Built	When Given General Repairs	Water Capacity	Coal Capacity	Total Weight Engine & Tender Loaded	Cost of Reproduction	Condition Per Cent	

Form 26
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company_____
Passenger Equipment on System_____Cars
Passenger Equipment Assigned to Minnesota_____Cars
Passenger Car Mileage System_____Miles
Passenger Car Mileage, Minnesota_____Miles

Field Inspector
Office Compiler

PASSENGER EQUIPMENT

Serial Number	Kind of Equipment	Class	Dimensions	Design of Vestibule	Kind of Coupler	Number of Seats	Kind of Heat	Kind of Light	Trucks Number of Wheels	Brake Equipment	Name of Builder	When Built	Total Number of Cars Now in Service	Cost of Reproduction	Condition Per Cent	Give Number of Cars Each Series Assigned to Minnesota

Form 27
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company_____
Freight Car Mileage, System_____Miles
Freight Car Mileage, Minnesota_____Miles

Field Inspector
Office Compiler

FREIGHT CAR EQUIPMENT

Include Cabooses in this Statement.

Serial Numbers	Class of Equipment	Sills and Body Steel or Wood	Dimensions	Capacity	Kind of Couplers	Size of Journals	Brake Equipment	Name of Builder	When Built	Number of Cars Now in Service	Cost of Reproduction	Condition Per Cent	REMARKS

Form 28
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company_____

Field Inspector
Office Compiler

MISCELLANEOUS EQUIPMENT

Include Snow Plows, Flangers, Steam Shovels, Pile Drivers, Derrick Cars, Dredges, and all Special Equipment, Located or used in Minnesota.

LOCATION	DESCRIPTION	Name of Builder	Age	Cost of Reproduction	Condition Per Cent

FIG. 14.

Form 14
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company _____
Section Number ___ From _____ To _____

STATION BUILDINGS AND FIXTURES

Including Station Equipment and Platforms

_____ *Field Inspector*
_____ *Office Compiler*

LOCATION	BUILDING					EQUIPMENT		PLATFORMS					
	Material	Dimensions	Age	General Description	Condition Per Cent	Office and Waiting Room Items	Condition Per Cent	Wood Square Ft.	Cinders Square Ft.	Concrete Square Ft.	Brick Square Ft.	Square Ft.	Condition Per Cent

Form 15
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company _____
Section Number ___ From _____ To _____

MISCELLANEOUS BUILDINGS

Including General Office Buildings, Warehouses, Elevators, and all Other Buildings Not Specifically Called for in Blank Forms

_____ *Field Inspector*
_____ *Office Compiler*

LOCATION	GENERAL DESCRIPTION					REMARKS
	Material	Dimensions	Age	Cost of Reproduction	Condition Per Cent	

Form 16
MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

Name of Operating Company _____
Section Number ___ From _____ To _____

ENGINE HOUSES AND TURNTABLES

_____ *Field Inspector*
_____ *Office Compiler*

LOCATION	ENGINE HOUSES														TURNTABLES							TURNTABLE PITS					
	MATERIAL OF			No. of Fire Walls	Depth of Stalls	Number of Stalls	PITS			HEATING		SMOKE JACKS		Age of Building	Condition Per Cent	Type of Table	Length Feet	Built By	Loading Specifications Tons	Turning Apparatus	Age of Table	Condition Per Cent	Center Foundation	CURBING		Kind Paving	Condition Per Cent
	Foundations	Walls	Framing				Number	Material	Dimensions	Steam	Hot Air	Kind	No.											Kind	Cubic Yds. B.M. Feet		

FIG. 15.

Form 17

Name of Operating Company_____

Section Number____ From_____ To_____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

CINDER PITS AND TRACK SCALES

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	CINDER PITS AND HOISTS					TRACK SCALES						REMARKS
	Material of Pit	Dimensions	Age	Pneumatic or Power Hoists, General Description	Condition Per Cent	LOCATION	Name of Manufacturer	Material of Foundation	Dimensions	Capacity Tons	Condition Per Cent	

Form 10

Name of Operating Company_____

Section Number From_____ To_____

Length of Main Line Roadway____ Miles____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

FENCES CATTLE GUARDS AND SIGNS

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	RIGHT OF WAY FENCES									SNOW FENCES				CATTLE GUARDS						HIGHWAY CROSSINGS			MISCELLANEOUS ROADWAY SIGHTS		
	WOOD FENCE				WIRE FENCE					TEMPORARY & PERMANENT				WOOD			IRON			PLANKING USED					
	No. Boards Per Panel	No. Posts Per Mile	No. Wires Sngl. Line	Condition Per Cent	No. Wires Per Panel	No. Posts Per Mile	No. Miles Sngl. Line	Condition Per Cent		Length Per Panel	B. M. Ft. Per Panel	Total Length in Lineal Feet	Condition Per Cent	Kind	Number	Condition Per Cent	Kind	Number	Condition Per Cent	Number of Crossing	Total B. M. Ft. Used	Condition Per Cent	Kind	Number	Condition Per Cent
																							Mile Posts		
																							Whistling Posts		

Form 1

Name of Operating Company_____

Section Number____ From____ To____

Length of Main Line Roadway____ Miles____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

LANDS FOR RIGHT OF WAY, YARDS AND TERMINALS

Separate by Counties, and for Incorporated Cities, Villages and Towns
Show Joint Right of Way Separately and Indicate Division of Ownership

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	Name of County	Name of Incorporated City, Village, or Town	WIDTH OF RIGHT OF WAY					Total Acres Right of Way	Average Market Value Per Acre	Average Right of Way Value Per Acre	LANDS FOR YARD AND TERMINALS		Average Market Value Per Acre	Average Value for Railway Purposes Per Acre	REMARKS
			FEET	FEET	FEET	FEET	FEET				LOCATION	Total Acres			
			Miles	Miles	Miles	Miles	Miles								

FIG. 16.

Form 18

Name of Operating Company _____

Section Number _____ From _____ To _____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

_____ *Field Inspector*

_____ *Office Compiler*

STEAM & ELECTRIC POWER PLANTS—GAS PLANTS

Include all Shafting, Belting, Motors, Etc., Operated from Central Plant

	LOCATION	Kind of Plant	GENERAL DESCRIPTION								
			POWER BUILDING					POWER EQUIPMENT			
			Material	Dimensions	Age	Cost of Production	Condition Per Cent		Cost of Production	Condition Per Cent	

Form 19

Name of Operating Company _____

Section Number _____ From _____ To _____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

_____ *Field Inspector*

_____ *Office Compiler*

GENERAL REPAIR SHOPS

	LOCATION	MOTIVE POWER AND REPAIR SHOP							
		Dimensions	MATERIAL USED FOR			Age Years	General Description and Purposes for Which Each Building is Used	Cost of Reproduction	Condition Per Cent
			Foundations	Walls	Frame				

Form 20

Name of Operating Company _____

Section Number _____ From _____ To _____

Located at _____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

_____ *Field Inspector*

_____ *Office Compiler*

SHOP MACHINERY AND TOOLS

Separate by Buildings in Which They are Located

Shafting, Belting, Motors, Etc., to be Included on Form No. 18 Power Plants

	MACHINES WITH ACCOMPANYING TOOLS					MACHINES WITH ACCOMPANYING TOOLS					MACHINES WITH ACCOMPANYING TOOLS					REMARKS
	Name of Machine	Name of Maker	Age	Cost of Reproduction	Condition Per Cent	Name of Machine	Name of Maker	Age	Cost of Reproduction	Condition Per Cent	Name of Machine	Name of Maker	Age	Cost of Reproduction	Condition Per Cent	

FIG. 17.

Form 7

Name of Operating Company_____

Section Number____ From____ To____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

PILE BRIDGES AND TIMBER TRESTLES

Include Timber Overhead Highway Bridges Erected at Expense of Railway Company

Field Inspector

Office Compiler

	LOCATION	GENERAL DESCRIPTION				PILES			CAPS			FRAMED BENTS			SUPERSTRUCTURE FOR PILE OR FRAMED BENTS									Structure Average Condition Per Cent	
															STRINGERS			TIES			GUARD RAILS				
		Bridge Number	Total Length	Average Height	Number of Bents	Kind of Timber	Number of Piles Per Bent	Total Lineal Feet Pilling	Kind of Timber	Dimensions	Number of Caps	Kind of Timber	Dimensions	B.M. Feet Including Sills and Caps	Kind of Timber	Dimensions	No. per Span	Kind of Timber	Dimensions	Number of Ties	Kind of Timber	Dimensions	Lineal Feet		

Form 8

Name of Operating Company_____

Section Number____ From____ To____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

CULVERTS

Include all Arch, Box, Cast Iron or Vitrified Pipe Culverts Stone, Concrete, or Wood

Field Inspector

Office Compiler

	LOCATION	Culvert Number	Design	Material	Dimensions	MASONRY		Concrete Cubic Yards	PAVING		Timber B.M. Feet	Age	Condition Per Cent	REMARKS
						Class	Cubic Yards		Material	Cubic Yards				

Form 9

Name of Operating Company_____

Section Number____ From____ To____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

TRACK AND BRIDGE TOOLS

Field Inspector

Office Compiler

	LOCATION	TRACK TOOLS ASSIGNED TO SECTIONS					BRIDGE TOOLS ASSIGNED REGULAR CREWS					NOTE:-
		Number of Section	HAND CARS		TOOLS		LOCATION	HAND CARS		TOOLS		In Space Below, List Kind and Number of Tools in use by Average Section and Bridge Crew, Covering General Track and Bridge Work
			Number	Condition Per Cent	Number of Sets	Condition Per Cent		Number	Condition Per Cent	Number of Sets	Condition Per Cent	

FIG. 18.

Form 11

Name of Operating Company_____ MINNESOTA RAILROAD & WAREHOUSE COMMISSION

Section Number____ From____ To____ RAILROAD APPRAISAL OF 1906

Field Inspector

Office Compiler

STOCK YARDS AND APPURTENANCES

LOCATION	YARDS								WATER SUPPLY AND POWER								STOCK SCALES			
	Number of Pens	Dimensions	Number of Gates	Sheds and Dimensions	Age	Condition Per Cent	PAVING Kind	PAVING Square Feet	WELLS Diameter	WELLS Depth	Other Means of Supply and Description	Pumps	WIND MILLS Size Wheel	WIND MILLS Tower, Kind and Height	Other Power Used, and Description	Cond Per Cent	Kind	Capacity Tons	Dimensions of Platform	Cond. Per Cent

Form 12

Name of Operating Company_____ MINNESOTA RAILROAD & WAREHOUSE COMMISSION

Section Number____ From____ To____ RAILROAD APPRAISAL OF 1906

Field Inspector

Office Compiler

WATER STATIONS

LOCATION	Source Supply If Well, Give Diameter and Depth	PUMP HOUSE				POWER									PUMPS								WATER TANKS				WATER CRANES						
		Material	Dimensions	Age Years	Condition Per Cent	BOILERS Horizontal Vertical	BOILERS Dimensions	BOILERS Cond. Per Ct.	GAS ENGINES Kind	GAS ENGINES H.P.	GAS ENGINES Cond. Per Ct.	WIND MILLS Kind	WIND MILLS Tower, Kind and Height	WIND MILLS Diam. Wheel	WIND MILLS Cond. Per Ct.	Kind	Diameter of Cylinder	Condition Per Cent	SUCTION PIPE Diam.	SUCTION PIPE Length	DISCHARGE PIPE Diam.	DISCHARGE PIPE Length	DISCHARGE PIPE Cond. Per Ct.	Diameter	Capacity Gal.	Tower, Kind and Height	Condition Per Cent	Kind	Diam. Column	Condition Per Cent	SUPPLY PIPE Diam.	SUPPLY PIPE Length	SUPPLY PIPE Cond. Per Ct.

Form 13

Name of Operating Company_____ MINNESOTA RAILROAD & WAREHOUSE COMMISSION

Section Number____ From____ To____ RAILROAD APPRAISAL OF 1906

Field Inspector

Office Compiler

COAL STATIONS

LOCATION	Type Chute or Crane	GENERAL DESCRIPTION OF BUILDING						APPROACH			SPECIAL APPLIANCES FOR HOISTING AND CONVEYING	
		Kind of Foundation	Dimensions of Building	Number of Pockets	Total Capacity Tons	Age of Building	Condition Per Cent	Design	Length	Condition Per Cent	General Description	Condition Per Cent

FIG. 19.

Form 1 A

Name of Operating Company_____

Section Number_____ City of_____

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

RAILWAY TERMINAL PROPERTY

_____ *Field Inspector*

_____ *Office Compiler*

	TERMINAL MAP	SECTION NO.	DESCRIPTION OF PROPERTY OWNED	TOTAL ACRES OWNED	Average Market Value Per Acre	Average Right of Way Value Per Acre	TOTAL VALUE

Form 2

Name of Operating Company_____

Section Number_____ From_____ To_____

Length of Main Line Roadway_____ Miles

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

ROADWAY REPORT

In Recording Information, Show Main Tracks Separate from Passing, Side, and Industry Tracks; Show Joint Tracks Separately, and Indicate Division of Ownership. The above does not apply to Grading or Protection except for Joint Tracks.

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	Acres Clearing and Grubbing	GRADING—CUBIC YARDS—PAY QUANTITIES					PROTECTION				CROSS TIES						SWITCH TIES (Including Head Blocks)						
		EXCAVATION			EMBANKMENT			RETAINING WALLS					Oak	Cedar	Hemlock	Other Kinds		B.M. Feet Per Set	Number of Sets					
		Earth	Loose Rock	Solid Rock	Earth	Loose Rock	Rip Rap Cu. Yds.	Dry Wall Cu. Yds.	Mortar Wall Cu. Yds.	Concrete Wall Cu. Yds.	Dimensions	Number	Number	Number	Number	Cond. Per Cent		Oak	Pine	Hemlock	Other Kinds	Cond. Per Cent	

Form 3

Name of Operating Company_____

Section Number_____ From_____ To_____

Length of Main Line Roadway_____ Miles

Length of Passing, Side and Industry Tracks_____ Miles

MINNESOTA RAILROAD & WAREHOUSE COMMISSION
RAILROAD APPRAISAL OF 1906

ROADWAY REPORT

In Recording Information, Show Main Tracks Separate from Passing, Side, and Industry Tracks; Show Joint Tracks Separately, and Indicate Division of Ownership

_____ *Field Inspector*

_____ *Office Compiler*

BALLAST						RAILS (Insert Weight of Rail per Yard)																		
LOCATION	Miles	Kind of Material	Width at Crown	Average Depth Under Tie	Condition Per Cent	LOCATION	Time in Service Years	New When Laid Miles	Relaying Rails Miles	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent	Wt. Track Miles	Cond. Per Cent

FIG. 20.

Form 4

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

ROADWAY REPORT

In Recording Information, Show Main Tracks Separate from Passing, Side, and Industry Tracks; Show Joint Tracks Separately, and Indicate Division of Ownership.

Name of Operating Company_____

Section Number_____ From_____ To_____

Length of Main Line Roadway_____ Miles

Length of Passing, Side, and Industry Tracks_____ Miles

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	Weight of Rail	TRACK FASTENINGS																											
		ANGLE BARS				Weight of Rail	FISH PLATES				BOLTS			NUT LOCKS					SPIKES			TIE PLATES				RAIL BRACES			
		No. of Pairs	Weight Per Pair	No. Bolts Per Joint	Cond. Per Cent		No. of Pairs	Weight Per Pair	No. Bolts Per Joint	Cond. Per Cent	Size	No. Kegs 200 lbs. Used	Cond. Per Cent	Kind	Size	No.	Weight Per 1000	Cond. Per Cent	Size	No. Kegs 200 lbs. Used	Cond Per Cent	Kind	No.	Weight Each	Cond. Per Cent	Kind	No.	Weight Each	Cond. Per Cent

Form 5

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

ROADWAY REPORT

In Recording Information, Show Main Tracks Separate from Passing, Side, and Industry Tracks; Show Joint Tracks Separately, and Indicate Division of Ownership.

Name of Operating Company_____

Section Number_____ From_____ To_____

Length of Main Line Roadway_____ Miles

Length of Passing, Side, and Industry Tracks_____ Miles

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	SPLIT SWITCHES			STUB SWITCHES			SWITCH STANDS			SWITCH LAMPS			RIGID FROGS						SPRING RAIL FROGS						GUARD RAILS				RAILROAD CROSSINGS				
	Complete Including Connecting Rod			Complete Including Connecting Rod										LENGTH IN FEET						LENGTH IN FEET						LENGTH IN FEET								
	Wt. Rail	No.	Cond. Per Cent	Wt. Rail	No.	Cond. Per Cent	Kind	No.	Cond. Per Cent	Kind	No.	Cond. Per Cent	Wt. Rail				Total No. of Each Kind	Condition Per Cent	Wt. Rail				Total No. of Each Length	Condition Per Cent	Wt. Rail			Total No. of Pairs	Condition Per Cent	Wt. Rail	Name of Railway Crossed	Per Cent Cost Paid By This Co.	Per Cent Maint. Paid By This Co.	Condition Per Cent

Form 6

MINNESOTA RAILROAD & WAREHOUSE COMMISSION

RAILROAD APPRAISAL OF 1906

BRIDGES

Truss, Plate Girder, I Beam and Draw Spans.

Indicate Power Used for Operating Draw Spans.

Name of Operating Company_____

Section Number_____ From_____ To_____

_____ *Field Inspector*

_____ *Office Compiler*

LOCATION	Bridge Number	SUB-STRUCTURE											SUPER-STRUCTURE													
		PILES		FRAMED TIMBER		MASONRY		CONCRETE		Average Height of Piers & Abutments	Age	Average Cond. Per Cent	No. of Spans	Total Length of Bridge	Design of Bridge	Specifications for Live Load	Total Weight of Steel in Bridge	Age	Cond. Per Cent	BRIDGE TIES			GUARD RAILS			Average Cond. Per Cent
		Kind of Timber	Total Lineal Feet	Kind of Timber	B.M. Feet	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards											Kind of Timber	No. of Ties	Dimensions	Kind of Timber	Dimensions	Lineal Feet	

FIG. 21.

Railroad Commission of Washington, the following general statement as to methods is gleaned:

The plan involved, not only a determination of cost of reproduction and present value, but also original cost.

The appraiser was unable to adopt the methods followed in Wisconsin and Minnesota, in so far as they accepted the inventory of the railroads, but made his own examinations of records. The railroads of the State denied that they had any information whatever that would be of value to the Commission.

The records of the Engineering Department were examined. The records of the Accounting Department were analyzed, various annual reports were examined and a corporate history of the road prepared.

Special forms for securing information were not prepared, and no rules, or definite order of procedure to be used for all roads alike, were adopted.

It is somewhat difficult to determine from the appraiser's report just what part of it covers actual work done, and what part is theory developed from the work, but presumably maps were prepared and profiles secured which represented the original conditions of construction.

The field inspection was made on hand-cars or on foot, each field inspector being furnished with the plans, profiles, etc.

The same conditions existed in Washington as elsewhere, that is, certain records were not kept up, and were found to be inaccurate and unreliable, and, as a result, the appraiser reported the condition to be such as "to cause much unnecessary work subsequently in checking."

A percentage of depreciation was not placed in the field, but was determined by "mortality tables," or by ascertaining the probable years of structure life, then determining from the age of the particular structure under consideration its percentage of depreciation, a method by no means new. It is not stated that any attempt was made to compare these tables with the rules of the Master Car Builders Association for valuing equipment, and no field inspection of equipment was made. The prevailing prices of materials formed the basis for estimating the cost of reproduction.

The value of motive power and rolling stock was apportioned among the States on the basis of engine- and car-mileage.

The land values were fixed by the Railroad Commission sitting as a court; real estate men from the large cities, real estate experts brought by the railway companies, and others testified; and, based on this testimony, the value was determined by the Commission in the same manner as in a condemnation case. Three right-of-way experts, all of whom had had experience in purchasing right of way for roads, were in the regular employ of the Commission, and details as to present values were referred to them.

The chief point of difference between this work and that of the other States apparently was the effort to ascertain first cost of the properties plus additions. This was done by an examination of the accounts of the railway companies.

The result of the Washington work, as far as rate-making is concerned, is indeterminate, as the United States Courts have held that the Commission may not fix freight rates. The Supreme Court of the State has held that they could. The Supreme Court has also held that the Tax Commission should accept the findings of the Railroad Commission for the purpose of taxation, with the result, as stated by Mr. Gray, that more than $1 250 000 more was received last year than during any prior year from railroad taxes.

The report of the Washington appraiser differs widely from that for other States in that it is diffuse and does not present the methods clearly and systematically; it is difficult, indeed, to trace what was actually done. The writer is loath to criticize, but this report is such as to suggest comment on a number of points.

1.—Throughout the report very great stress is laid on the cost of making the appraisal. Such an undertaking as an appraisal of corporation property should be done thoroughly or left alone. It matters not whether the work of Professor Cooley or Professor Taylor cost $5 a mile or $50 a mile, if a dependable result was secured. It does not appear to be good taste either to criticize costs of work in other States, or compare the costs in Wisconsin and Michigan with the costs in Washington.

2.—A number of criticisms, amounting almost to reflections, are made on the methods elsewhere. The appraiser says:

"Speaking for myself, I found the precedents established by Texas, Michigan, and Wisconsin of little value either in deciding the methods to be pursued in making the appraisals or in estimating the probable cost of appraisal. * * *

"In estimating present or depreciated values of structures, rolling stock, etc., both Michigan and Wisconsin had sent experts into the field to estimate the percentage of present value to each unit. In this manner 40 000 freight cars were inspected in Michigan and their 'present value' estimated. To me this seemed to be not only a useless procedure but very erroneous. * * *

"The appraisals heretofore made in other states have been based almost entirely upon field surveys and inspection, no attempt having been made to secure the necessary data from the engineering and accounting records of the railways. Why? The answer is found in the purpose of the appraisal."

Such sentences, and others which, by inference if not by name, reflect on work executed by men of high professional standing, are hardly in good taste, even if true, in a report to a railroad commission of another State. Whether or not he found little of value, the appraiser's general line of procedure was not radically different from that followed in Michigan and Wisconsin in getting all available data first from the companies, then in making a field inspection before fixing values. If misled by erroneous profiles, he went into an error needlessly, as it was fully known in Michigan that records were in the condition described before any field work was begun.

The inspection of freight cars in Michigan was not to "estimate present value" but to determine at first hand whether the Master Car Builders rules for valuation were safe to use, and to back up their use in Court.

The third paragraph quoted is a misstatement, due clearly to a misapprehension of what really was done.

3.—The spirit of suspicion of railroad men's motives is an unfortunate one to carry into a railroad appraisal, much less into a report.

4.—The writer fully realizes the magnitude of the task before the appraiser who is asked to determine first cost plus improvements or betterments.

Hardly a trunk line road exists to-day that has not grown up from a small beginning, changed its line, reduced its grades, added safety devices, changed the type of its bridges and buildings, increased the weight of its rails, put in service much heavier equipment, in fact, completely changed everything, except, perhaps, the original right of way.

The task of securing from old accounting department records an accurate statement of cost is—and the writer says it with the confidence

born of experience—an impossibility. It is a job of such magnitude as to be practically prohibitive. The different systems of accounting, the different policies of the management, as to charging betterments to capital or operating expense, to say nothing of the countless errors that creep into the distribution of accounts, place such an undertaking among the labors of a modern Hercules, and, to one who has been engaged even in the task of trying to ascertain what one year's accounting on a large road may do in concealing betterments under the guise of operating expense, it would appear that a result that could be sworn to as correct was impossible of attainment along the lines suggested in this report.

The general question of the propriety of the use of mortality tables is discussed elsewhere in this paper.

This document, as an addition to the literature of the subject of valuation of properties, is disappointing, for if there were original and valuable methods they are not explicitly described.

The cost of making the appraisal was about $13 per mile of line.

The Valuation of Traction Properties in Chicago.

During 1906 a complete valuation of the property and franchises of the surface roads of Chicago was made under the direction of a Commission consisting of Bion J. Arnold, M. Am. Soc. C. E., and Messrs. Mortimer E. Cooley, and A. B. du Pont. The report of this valuation was published in the form of a pamphlet which is now practically out of print, as all extra copies were long ago exhausted.

The instructions of this Commission from the Chicago City Council were:

"To consider the detailed inventories and estimates of value to be submitted by the Street Railway Companies, to investigate the same and to ascertain whether the values thus listed were reasonable, fair and just."

Detailed inventories and estimates of value were submitted by the roads, and, from time to time during the progress of the work, additions or corrections to these schedules were made.

Reports showing income, operating expense, and traffic statistics were made, and such detailed statements as were called for from time to time were furnished.

The Commission organized its force for valuation work by using the office and field organization of the Arnold Company under the di-

rect charge of George Weston, M. Am. Soc. C. E., for the major part of the work, and retained Messrs. Theodore H. Hinchman, Jr., C. V. Conover, and the writer to give special study to certain features of the appraisal. In the determination of franchise values, Professor Henry C. Adams was retained in consultation by the Commission.

In arriving at the value of the physical properties, a complete field examination was made, depreciation determined, cost of reproduction estimated, and in general, the work was carried on along lines quite similar to those of the railway appraisals heretofore described in detail.

Several very interesting and unique problems were presented, some of which were as follows:

"Upon what basis shall the cable properties of the companies be estimated—(*a*) as operating cable systems, or (*b*) as obsolete systems having no value except so far as the physical property can be utilized in the conversion of the cable lines into electric?"

In the final conclusions of the Commission, part of the cable lines were treated in one way, and part in the other.

"What allowance, if any, shall be made for the pavements laid by the companies on their right of way?"

The discussion of this topic, together with the opinions of counsel as to the legal status, is of interest. The Commission did not consider the value of paving as constituting any part of the physical property, the value of which must be supported out of earnings. The present value of the pavement was estimated and reported without specific recommendation as to whether an allowance should be made.

The valuation of real estate was left in the hands of real estate experts familiar with values in Chicago, each piece of property being personally examined and valued, and the representatives of the roads given such hearings as they desired.

In computing the value of physical properties, an allowance of 10% was made to cover the following items:

"*1.—Legal Expenses*—including those incurred in securing right of way and frontage consents.

"*2.—Interest or carrying charge* for the money expended during the construction period and up to the time the property goes into operation.

"*3.—Brokerage*—or the expense of securing the necessary moneys.

"*4.—Contingencies*—to cover incomplete inventories, unforeseen difficulties of construction, and any and all other items of expense which cannot be foreseen."

The only novel feature in this list is Item 3, which was not included specifically in any of the railroad valuations made by States and heretofore described.

The franchise and intangible property valuation, amounting to some $9 000 000, or about one-fifth of the total, was a very important phase of the work, and the Commission gave up a large part of the report to its discussion.

The difficulties in this part of the work are described as threefold:

"*First.*—The difficulty of determining what are the exact legal rights of the companies in any given street or part of street, in absence of a direct and final judicial decision as to these rights;

"*Second.*—The difficulty in estimating the value of a line of street railways, consisting of several parts, where each of these parts is operated under a different tenure due to the character of the ordinances or franchises, respectively; and

"*Third.*—The difficulties arising from the absence of exact information as to the receipts and expenditures on the several parts of a single line covered by franchises of different length and character."

The Commission, having arrived at such an adjustment of the difficulties as appeared just, determined the value of franchises in the following manner:

It was assumed that the gross earnings on the different parts or routes of each system were in proportion to the car-mileage.

The system was divided into routes, and the car-mileage was determined for each route; then this information was compiled so as to show the car-mileage, and consequently the gross earnings, apportionable to each franchise.

The next step was to determine, in the same manner, the proportion of operating expenses assignable to each franchise, the operating expense being assumed to be uniform with gross earnings. A study of the conditions in Chicago resulted in a determination upon 70% as a fair proportion for operating expenses, taxes, and maintenence.

Next, the amount of capital investment to be supported out of earnings was computed by estimating the cost of reproduction of track and overhead lines under each franchise and apportioning the cost of land, power-houses, barns, cars, tools, and stores in proportion to car-mileage.

In determining earnings for the unexpired years of franchise life, it was assumed that the earnings would increase in accordance with the law laid down by Mr. Arnold in 1902.

The last step was to find the value of the net earnings of future years, after deducting the sum required to support the invested capital. The rate chosen was 5% compound interest. The sum of the different present values thus found was the value of the franchise sought.

Two other points arising in connection with franchise values were:

"Where, on a street, franchises covering part of the street have expired, and others remain in force, the contention of the city is that the expired franchise is valueless because traffic under it can be stopped; that of the company is that it still has value, as traffic can be routed over other streets where franchises have not expired."

This was set aside on the ground that the value of any particular portion of a street, or of a franchise, remains the same as long as the system is considered as an entirety.

The second point was as to the value of traffic agreements; but this complicated problem was also dismissed on the theory that when two systems are considered as co-operating, the value of individual parts of either system remains the same regardless of their ownership.

The values of their properties, fixed by the companies, included paving. The total figures reached in this valuation were:

Companies' valuation,	including	paving,		$73 555 675
Commission's	"	"	"	50 994 782
Commission's	"	excluding	"	46 652 747

This work affords many interesting problems, and is perhaps the largest valuation for determining a price for the purchase of property that had been made to date.

The Commercial Valuation of Railway Operating Property of the Department of Commerce and Labor.

In 1902 the permanent Census Office was established, and the Director was authorized to collect statistics relative to public indebtedness, valuation, taxation, and expenditures. The Bureau of the Census co-operated with the Department of Commerce and Labor in the preparation of the appraisal of the commercial valuation of railway properties of the country.

The report of this work, issued as Bulletin 21 of the Bureau of the Census, is the most interesting and valuable exposition of the subject of railway valuations yet published, as it includes not only the report of this particular work, together with the results, tabulated by States,

but appendices describing and discussing the work in States and foreign countries, and the work of valuation by railway men.

The results are of prime interest, as they show the valuation of all railway property in all the States, based on uniform methods of appraisal and distribution, which enables a comparison to be made with work done by the States.

The method adopted in this work was so radically different from that of the various State appraisals as to make a detailed description a matter of interest, and it is to be regretted that it cannot be included. The method is really a capitalization of net earnings.

Owing to the nature of the inquiry, namely, to determine what part of the wealth of the nation is devoted to railway transportation, it was obligatory on the appraisers to adopt a method which would disclose as nearly as possible the true market value.

Certain restrictions and limitations on the term, "value," and on the use of the resultant figures of the appraisal, are suggested by Professor Adams, as follows:

"The valuation submitted in this report may be properly defined as the commercial value of property used by railways in connection with the business of transportation. By 'commercial value' is meant the estimate placed upon the worth of property regarded as a business proposition. This must, of course, be the market estimate and not the arbitrary estimate of a public official. The two fundamental considerations by which the market is influenced in placing a value upon property when bought or sold, are the expectation of income arising from the use of the property, and the strategic significance of the property. These two considerations are made the basis of the valuation of railway property submitted in this report. The material made use of in this valuation is, first, the operating and financial accounts of the railways; second, interrailway contracts and agreements; and, third, the published records of the stock market.

"This is no place to enter upon a discussion of the nature and classification of different kinds of value, but a word of caution may be allowed in order to guard against an unwarranted use of the figures here submitted. The commercial valuation of railway property, in so far as it depends on income arising from the sale of transportation, is the result, among other things, of an established schedule of freight and passenger rates, from which it follows that such a valuation cannot be used for determining the reasonableness or unreasonableness of the rates in question. The solution of the rate problem demands a separate valuation of the physical property.

"Again, in so far as the Government is precluded by its political character from following commercial rules in the sale of any service which it renders, a commercial valuation which assumes that property is administered under the rules of private rather than public financiering, might differ from the valuation of the same property regarded as a public property. The purpose of this remark is to preclude a discussion of the problem of the Government purchase of railways on the basis of the values submitted in this report. It would of course be necessary to modify these values by considerations of public utility, in order to determine a public purchase price.

"Whether or not the commercial valuation here submitted can be used as the basis of assessing railway properties for the purpose of taxation depends entirely upon the taxing laws of the state for which the question is asked. If these laws confine the appraisal of railway property to its physical elements, the values here submitted would, in the case of prosperous roads, exceed an appraisal for the purpose of taxation. If, on the other hand, it is the purpose of the taxing law to appraise railway property at its true cash value, unusual or abnormal conditions being excluded, it may be that the commercial valuation of operating property submitted in this report fairly measures its appraisal for the purpose of taxation."

The methods are explained in the most minute detail by a series of papers in the Bulletin.

The work of Professor Adams and his associates is of great practical value in that it shows the discrepancy in the taxation laws of the different States as relating to railroad properties, and in that it gives a set of values determined by a uniform method, which, within reasonable limits, furnishes a check on the work of the State appraisals.

This method, of course, cannot be used for purposes of rate-making, or of bond or stock restrictive legislation, but the general uniformity of its results with those of State appraisals, and the radical differences noted in the case of values for taxation in other States, lead very properly to the inference that a value determined by this method is very close to the truth.

The Extent of Appraisal Practice.

There have been many appraisals of property besides those reviewed in the foregoing pages. Several excellent contributions to valuation literature, as a result of the numerous water-works appraisals, are mentioned in the Appendix.

New Jersey and Nebraska have had railway appraisals in progress during 1909-10. At the time of writing, neither appraisal has gone

far enough to add any points of interest to the subject, except as the appraisers in these two States discuss the subject and bring out new points.

Valuations of street railway property have been made in several cities, Cleveland, Ohio, Detroit, and Milwaukee being the most recent.

The Cleveland and Milwaukee hearings have produced large records, and have tended to determine finally certain principles of valuation. Several valuations have also been made for corporations, among which may be mentioned that of The Toledo Railways and Light Company, by Messrs. Ford, Bacon, and Davis, and that for the New York, New Haven, and Hartford Railway, under the direction of John F. Stevens, M. Am. Soc. C. E.

This latter valuation offers some very interesting points, and, in view of Mr. Stevens' standing as a railroad engineer, the adoption by him of methods of inventory and field inspection would go far toward fixing a precedent which would be acceptable to the railroads. It is to be regretted that the interests of the road are such that it is not deemed wise by its President to discuss even the principles of this work at present.

In connection with the recent appraisal made by the City of Detroit, The Detroit United Railway made an independent examination and appraisal of its own property, with the double purpose of furnishing an inventory to the city and of checking the work of the staff employed by the city. This work for the railroad was done by officials and employees of the company, under the personal direction of Mr. R. B. Rifenberick. It is noteworthy for the completeness of its inventory, which goes into the most minute detail, and for the excellence of the maps and drawings which accompany it and show, not only every standard type of track, rail, and all buildings and machinery, but every piece of track and overhead special work on the entire system. This appraisal includes a most complete and exhaustive study of average unit costs. Inasmuch as this work is likely to be fully reviewed in the Courts in the near future, any further description would hardly be proper. It is not too much to say, however, that it probably stands as the most complete in every detail, as to inventory and records, of all American appraisals up to this date.

During the summer of 1910 the Railway Commission of Michigan ordered an appraisal of certain large electric-power properties of the

State. This work was done by Professor Mortimer E. Cooley, assisted by Mr. Henry C. Anderson and the writer. This appraisal, involving certain comparatively new corporations, made it possible to obtain a fairly definite solution of some of the problems relative to overhead charges.

It is evident that the demand for valuation work of a high character will increase, and that it will come, not only from States and cities, but from corporations. Much of the work done in the past has not been described in the publications of scientific societies; much very valuable work has secured only partial notice through reports of litigation; and it is undoubtedly true that the most complete and full discussions of the principles of valuation have been in the form of expert evidence before the Courts, and are buried in the mass of unprinted records of testimony.

Review of Some Methods of Valuation, and Some of the Criticisms on the Michigan Appraisal.

Much of the available literature on the subject of valuations is in the form of papers descriptive of water-works appraisals and arbitrations, many of which have been made, and a few of which have been the subject of valuable papers and discussions before learned societies.

Before the American Water-Works Association, D. W. Mead and J. W. Alvord, Members, Am. Soc. C. E., have presented papers* which have been quite fully discussed. The chief point of interest in these papers is the treatment of the intangible element termed "going value." Mr. Alvord advances the argument that, after the determination of physical present value, there should be added, to determine the fair value, two non-physical elements: the "going" or "business" value, and the franchise value. The first element is defined as that special value which is:

"Built up * * * by the energy, perseverance and solicitation of the officers in charge, as distinct from the inert plant itself, * * *.

* * * * * * *

"The element of 'going value' has been before described as the element of growth in the plant irrespective of its physical condition. It is comparable somewhat to that indefinable quality known in other lines of business as 'Good Will'. Nevertheless it is something more than good will in water works business, as it represents what might be

Proceedings, Am. Water-Works Assoc., 1902.

more aptly described as 'connected good will', that is to say, the acquisition of customers who have invested considerable sums in actually connecting their premises with the plant of the company, and provided appliances for the use of the water which it can deliver."

The method advocated by Mr. Alvord as the most rational one for computing this value is described as follows:

"It is assumed that a new plant will be constructed, the inception of which is coincident with the data of arbitration. Such new plant is to be of an equal capacity with the older plant under consideration, and a due allowance of time in which to construct this new plant, and the necessary capital to be invested in it from time to time is estimated. At the completion of this new imaginary plant, it is assumed that it commences to obtain business in that community from those who are not previously accustomed to the free use of public water, except in a general way; that it is to require the business ability and consequent increase in number of customers which the earlier and older plant went through within the early years of its existence. An assumption of the amount of business thus created for each year for a period of years in advance is carefully computed and estimated by the board of arbitration. The losses of interest upon capital invested are duly fixed, as well as the first absence and later addition of revenue from hydrant rentals, and a table is prepared showing each year, the total business developed and the total losses, if any. After this is completed a forecast is made of the business of the older works for the same period of time in the future that it takes the business of the new works to equal the business of the old works. If the business of the old works is found to be a growing one it will be a longer period that the new works will require to overtake it than will be the case if the business of the older works is stationary or decreasing. In general, the differences which might be called the debits and credits of this new imaginary plant and the debits and credits of the older working plant are reduced to their present worth at the time of appraisement, and an estimate is made up which will adequately represent the financial advantage which the old works (already fully equipped and in running order and having a large number of profitable customers) will have over the new works, where everything must be built and customers secured.

"It is necessary in making this supposititious estimate of the new plant to consider it in no way a competitor of the older works; there is not supposed to be competition between the new and the old, but it is left to the experience of the board of arbitration to consider how long it would take the new company to build new works, and build up business for the new works, until they have overtaken the business of the old company should it continue to occupy the same territory."

Mr. Alvord's description of his method has been quoted fully, as it is an interesting one and has been often used. It is open to the very decided objection that it is purely theoretical, a rational method of computation, perhaps, but based on assumption throughout. It may be said to be a method which is within the field of pure speculation. Mr. Alvord, himself, says that where experience in financial matters and the financial management of water-works is not brought into the valuation, there is usually to be found guesses of the wildest character. Professor Mead, in discussing Mr. Alvord's method and agreeing that it is consistent and logical, says:

"The method is by no means an exact one, and must necessarily lead to a very great divergence in opinions as to the 'going value,' in accordance with the assumptions on which it is based. * * * Its very logic is an element of danger, for if clearly presented from a biased stand-point to one previously unacquainted with its application, and if accepted without careful analyses it may lead to very unjust conclusions. If used, however, carefully and conscientiously with the desire to do justice to all concerned, it is a valuable method of estimating going value, and the only logical one with which the speaker is familiar."

In addition to the element of going or business value, Mr. Alvord considers the franchise value, and presents two methods for its determination:

First.—The physical value, depreciation, and going value are entirely neglected, and the entire valuation is fixed on the basis of its earning power throughout the remaining life of the franchise and its probable sale value.

The probable net revenue for each year of franchise life must be estimated and capitalized at a sum, which, if put at interest, would pay such yearly revenue and extinguish itself at the end of the franchise period. To this must be added the physical value of the plant at the end of the franchise period.

Second.—The cost of reproduction, depreciation, and present physical value are ascertained, and the going value computed. Then it is determined whether or not the net revenue is paying interest on a capitalized value greater than that indicated by the sum of the physical and business values. If such capitalized figure is less than this combined value, there is, of course, no franchise value; if it is more, there is a franchise value which should be determined by estimating, for the remaining

years of the franchise, the excess income over and above that necessary to cancel all obligations (including interest on the physical and business values), and the reduction of these several sums to a basis of present worth.

A number of other articles and papers are listed in the Appendix. Many of these are of great value and are well worth careful perusal, but they offer no definite plan of valuation. Inasmuch as the general principles involved in the valuation of a water-works plant and a railroad plant are similar, it is advisable, in any exhaustive study of the subject, to review the articles descriptive of water-works valuation, and it is a matter of regret that greater consideration cannot be here given to some of the points raised by such engineers as George H. Benzenberg, Past-President, Am. Soc. C. E., Kenneth Allen, Arthur L. Adams, Emil Kuichling, Members, Am. Soc. C. E., and others in their various papers and discussions of this subject.

The *Railway Age,* the *Railroad Gazette,* the *Railroad Age Gazette,* and the *Railway Age Gazette* contain many editorials and articles on the valuation of railroad properties. These are written mainly from the standpoint of the railway official, and present many matters of interest which are worthy of study prior to undertaking a large appraisal. One series of articles in the *Railway Age Gazette** is a most masterly argument, and it is to be regretted that the author has not disclosed his identity.

The Michigan valuation has been discussed in two papers by Mr. Charles Hansel, whose connection with the work, as a member of the Board of Review, gave him probably a more intimate knowledge of it than any one else, not connected with the actual working organization, who has undertaken to review the work. His first paper, published in 1901,† entitled, "What is the Value of a Railroad for Purposes of Taxation?" is a discussion of the work of Professors Cooley and Adams, written while the subject was fresh in his mind. His second paper, an able argument for a Government valuation, appeared in the *North American Review* in 1907. The one point to which special attention is drawn is Mr. Hansel's astonishing misconception of Professor Adams' plan of work. This misleading statement appears in the first paper and is reiterated in the second. It is of such a character

*Commencing with the issue of January 22d, 1909.

† The *Railroad Gazette*, April 19th, 1901, Vol. XXXIII, No. 16, p. 271.

that to pass it unchallenged would be doing great injustice to Professor Adams. He states Professor Adams' plan as follows: Capitalize net earnings and add to the present value of the physical appraisal as found by Professor Cooley.

"The result would be that in case the present value per mile as determined by Professor Cooley is found to be $15 000, and the net earnings by Professor Adams are found to be $1 000, this capitalized at 5 per cent. would equal $20 000, and added to the present value would make $35 000, which would be the sum upon which taxes were to be levied. In other words, if the company actually earns $1 000 it increases its value for purposes of taxation 20 times that amount. If, however, instead of having a net earning of $1 000 it spends that sum in improving the property, it has only increased its taxable property by $1 000."

This statement is not only inaccurate, but involves the other error of assuming that the appraisal figure was to be used for taxation. It was not. It was merely information to aid the legislature in framing new taxation laws. The chief error, however, is in assuming that Professor Adams added the value of the property, as determined by a capitalization of net earnings (which *per se* is a well-recognized method of valuation), to the value of the physical property. This error probably is due to the flood of criticism which at the time was aimed at any form of non-physical valuation.

Professor Adams finds the net earning in Mr. Hansel's example to be $1 000 per mile. From this, in the method actually used, he deducts an annuity for the support of invested capital, which he assumes to be the present value found by Professor Cooley. In the example given by Mr. Hansel he would deduct 4% on $15 000, or $600 per mile, leaving $400 per mile as surplus, or the earnings due to non-physical elements of value. This, capitalized at 5%, would give $8 000 per mile, which, added to Professor Cooley's figure of Present Value, would make $23 000 per mile, instead of $35 000, as stated by Mr. Hansel.

The most recent criticism of the Michigan valuation work was in an address* before the New York Traffic Club in January, 1909, by Mr. W. H. Williams, Third Vice-President of the Delaware and Hudson Company. This address is devoted to an attack, not only on the work of the Michigan appraisal, but on Professor Adams' work

* *Railroad Age Gazette*, April 2d, 1909, p. 761.

and on the propriety of valuation work being undertaken for any reason. The arguments advanced in this address are such that a discussion of them becomes almost necessary in any complete review of the Michigan work, and it contains so many statements which are erroneous that it would hardly be permissible to pass them without comment. The manifest impatience with all forms of governmental interference with corporations, which so often characterizes the utterances of prominent railway officials, appears in this paper to a marked degree. After stating that the present agitation for a physical valuation appears to be the result of a misconception, on the part of the Interstate Commerce Commission, of Section 20 of the Act to Regulate Commerce, and quoting Professor Adams' suggestion of an inquiry, he says:

"Subsequently, the desire of Governor Pingree to find a means of increasing railway taxation in Michigan gave Professor Adams an opportunity to experiment with his project within the limits of that State."

This is a direct imputation of an improper motive, not only to Governor Pingree, but to Professor Adams. As stated elsewhere, the investigation was to determine whether the railroads were paying taxes on the same basis of valuation as other property in the State—an absolutely proper proceeding. Professor Adams was associated with the Michigan appraisal, but had no connection whatever with the "physical valuation," to which such objection is taken, and his appointment was made after the work of physical valuation had been fully outlined and was well under way.

The opening statement is followed by a brief *résumé* of the recommendations of the Interstate Commerce Commission and President Roosevelt, and of bills introduced in Congress, also by quotations from Bulletin 21, describing the methods of valuation used in Michigan and a showing that practically a similar basis was used in other States. Mr. Williams then summarizes his objections to the Michigan work:

"(1) No allowance is made for discount on securities sold.

"Discount is a partial capitalization of the commercial risk had in making the investment, and it increases or decreases in proportion to the probability of the earning power of money under existing conditions. Not only is this practice justified by long-established commercial usage, but also by judicial determination."

The correctness of this position cannot be conceded on any grounds of economics or accountancy. It is answered conclusively in an article,* elsewhere referred to, as follows:

"There is considerable diversity of opinion as regards the proper treatment of discount on securities sold. There is a distinction between bonds, representing corporate indebtedness and having a definite limitation as to the time of their redemption, and share capital, representing ownership and which as a rule is irredeemable. In relation to the former there can be but one tenable view. If a company can market its 50-year 4 per cent. bonds at 90 per cent. of par, it means that the company's credit is on a 4½ per cent. basis; that it could market a like security paying 4½ per cent. at par. If it elects to issue at the lower rate it is merely sacrificing principal for the sake of a reduction in the annual interest charge; in other words, it is prepaying interest which would accrue during the life of the issue. If $10 000 000 par value were issued at 90 per cent., the discount would amount to $1 000 000, and the saving in interest to $50 000 per year, or $2 500 000 in 50 years. Obviously the company cannot claim the privilege of capitalizing the discount, while thereby availing itself of the reduction in interest. If such a course were legitimate in the case of a 5 or 10 per cent. discount, it would be equally so if the discount were 50 or 75 per cent., when the absurdity of the proposition would be perfectly apparent. The somewhat general practice of prorating the discount, as a charge against revenues, over the term of the obligation's existence is sound; but this should be done, not in equal installments, but on the basis of the appreciated value of the bond as it approaches par at maturity. There is no apparent objection to charging discount of this nature in a lump sum against an accumulated surplus. The capitalization of discount on stocks, involving as it does the introduction of fictitious values in capital assets, is wholly indefensible."

The writer has failed to note any particular "judicial determination" which approves of the charge of any such item to capital account.

"(2) The interest during construction (3 per cent.) is less than a fair and reasonable return on the investment."

The amount actually paid out for interest on money used during the period of construction will vary, of course, depending on the time of construction and the way in which payments on construction materials are made. On the basis of a rate of 6% per annum and construction lasting one year, only a very small portion of the construction cost will pay 6%, while the great items of rails, buildings, motive

Railroad Age Gazette, January 29th, 1909, p. 219.

power, and equipment will be put into the work from 90 days to 10 months after the commencement of work, and will actually bear but little interest. In the Michigan appraisal the assumption was made that all work must be replaced in one year, and that on long roads partial operation would commence as various sections of the line were completed; and 3% was agreed on as a fair average, perhaps having in mind Governor Pingree's "desire to increase railway taxation." Some assumption must be made. This one, that long roads, covering several years of construction work, are in Michigan put in partial operation as soon as built, is not unreasonable. Such an assumption clearly would not be proper in the case of long lines crossing mountains, or involving such a class of construction as to make it impossible to complete the property short of two or three years; and, in any such cases, the interest charge should be made sufficient to cover.

"(3) No allowance is made for working capital with which to carry on the business."

All the appraisals of physical property have been made on the basis of securing a figure representing the cost of reconstructing the property in the condition in which it existed on the date of the appraisal, including only items properly chargeable to capital, cost of road, and equipment. This is not such an item. The writer is of the opinion, however, that it is a proper one to determine and include in any report.

"(4) No allowance is made for wear and tear of material during the period of construction. Assuming eight years to be the life of a tie, and three years the period of construction, a substantial percentage of the period of usefulness is over before the road is in operation. The use of the rails before the track is put in proper line and surface hastens the time when they must be removed."

This deterioration is a necessary incident to any construction work. It has not been customary or usual to take account of it. To add to the amount capitalized on account of this item would be manifestly improper. The only way in which this could be cared for would be in an adjustment of the depreciation reserve when raised to cover that which takes place during the construction period. This reserve, later in the address, is objected to by Mr. Williams as improper accounting:

"(5) No allowance has been made for impact and adaptation. After the line is placed in operation, each fill will sink 1 ft. for every

10 ft. of height. The slope of cuts must be increased to prevent landslides and washouts. The ballast will pound into the roadbed, necessitating additional ballast to secure a standard cross-section."

Part of this objection is covered by the item, "Appreciation of Roadbed," discussed elsewhere. This, perhaps, is a proper item, but a comparatively small one. One of the examples cited is clearly maintenance. This objection is largely covered in the Michigan work by the contingency item.

"(6) A uniform price for earthwork was used, thus ignoring the varying character of soil and length of haul."

This is erroneous. On the Michigan appraisal prices were used for earth, loose rock, and solid rock. There is practically no classification in the Southern Peninsula of Michigan, or, in fact, on 90% of the mileage of the State. The price used was not much out of the way when considered as a fair average for the territory. The same was apparently true of other appraisals. It would not be a proper figure to use in an estimate based on 1909 prices, which are materially greater than those obtaining in 1890-1900.

"(7) A uniform price list for all materials was used, thus ignoring the source of supply and cost of delivery to point of use."

This, again, is not true. Differences were made between the Upper and Lower Peninsulas; and an exhaustive study was made of rates to different sections. It is believed that the prices adopted took all these points fully into consideration. It is true that no effort was made to use different unit prices as between counties, but, in a number of cases, differences in prices were made for different sections of the State, where either local conditions as to production of materials, or traffic rates, seemed to warrant.

"(8) No allowance was made for interference with work on account of labor troubles, condition of the weather, etc., which would vary materially in the different counties of the same state."

True. Nor is such allowance ever made in actual construction, beyond the contingency item. Such items are a frequent source of annoyance, delay, and sometimes of expense, but an expense difficult to separate and set up, and clearly belonging to contingencies.

"(9) No allowance is made for carrying charges until such time as the road was placed on a revenue basis."

True; and such item is not a part of a physical appraisal.

The foregoing nine points are classed as "among other things" open to criticism. The next two quoted paragraphs are introduced to indicate the "other things" as they appear. These are mainly non-physical or intangible elements of value, which, under the method of Professor Adams, are treated *en bloc,* and which, from their nature, it would be impossible to set out and value separately; therefore, no effort is made to answer them point by point, further than to say in general that, if there is any value attaching to these items, it was presumed to have been disclosed by the method of Professor Adams, and to suggest further that had Professors Cooley and Adams had such an advocate of intangible values ten years ago, their labors would have been lightened, as all arguments by railway officials at that time were against the use of any such elements of value in an appraisal.

"No consideration has been given to the leasehold interests. * * * Therefore it will be seen there remains to be determined many questions vitally affecting the value of the property without regard to its value as a 'going concern.'

"There should be no difference in the basis of arriving at the value, as a 'going concern,' of the property of a railway and any industrial establishment, nor should there be any difference in the basis of valuation for taxation [exactly what Governor Pingree maintained] or other purposes. There is common to both the value due to location, good will, etc."

While the remainder of the address in question contains no specific criticisms of methods of valuation, it does go into a discussion of sundry legal decisions; and conclusions are drawn quite at variance with those set forth elsewhere in this paper. The thing most noticeable in the entire address is the lack of a proper spirit of fairness, an apparent inability to state fully and fairly the position of the men whose views are being opposed, and an undue emphasis in quoting some public official whose views coincide for the time being with the theories which are being advocated. The fact that Mr. Williams quotes from an address of Hon. Robert H. Shields, President of the Michigan Tax Commission, a statement criticising the work of Professors Cooley and Adams, illustrates the latter point.

The statement is made again and again that the Michigan work was a physical valuation; that no attempt was made to secure a "fair value" (the language of the Courts), and that the value as a going concern was not attempted to be given. In no case is the statement

made that Professor Cooley had charge of the physical valuation in Michigan, and that Professor Adams took this physical valuation, and, under his method, treated it as one element, and with it and other data derived from a study of the reports and earnings of the company, undertook to determine a "non-physical," "intangible," "franchise," or "going concern" value, which included all tangible elements, and which, added to the physical value, was assumed by Professor Adams to give the true value. Had such a statement been fairly made, no possible objection could be raised to the making of any number of points against the correctness of the methods used by Professor Adams.

"Certainly it cannot be denied that a road between New York and Chicago, 950 miles in length, passing through a manufacturing district, is of greater value than a road 1 200 miles in length, between the same cities, but passing through a hilly and undeveloped territory a portion of the distance, and through a farming section for a greater portion of the remaining distance; yet the advocates of a physical valuation would have us believe that there is no difference in the value of the two if they can be reproduced to-day at the same cost."

This statement is entirely unfair to every man who has been in responsible charge of valuation work in recent years in the United States. No theory has ever been favored by any honest-thinking advocate of a valuation. In the first place, no interstate valuations have ever been made, and no parallel case to the one assumed is to be found, except for very short sections of roads, a very marked instance having been referred to elsewhere in this paper. Such a condition as assumed would be reflected in the earnings of the companies to such an extent as to cause the non-physical element of Professor Adams as used in Michigan to correct largely or wholly the inequality and inaccuracy of the physical valuation; such at least was the theory, and, if carried to its logical end by the use of negative non-physical values, such would be the result.

The final arguments of Mr. Williams' address are devoted to an attack on the plan outlined by the Interstate Commerce Commission for valuation, and on some of the accounting methods of the Commission—points not proper to be discussed in this paper—but it is difficult indeed to read them without noting the apparently studied misrepresentation of the real attitude of Professor Adams and the Commission, and the evident object of the entire address to create a

wrong impression regarding what has been done, and a prejudice against the men who have been engaged on State appraisal work and those who advocate the appraisal of properties as a proper step in the way of securing such information as will enable an intelligent consideration of the great corporation problems that must be solved.

The Determination of Elements of Value and Methods of Valuation by the Courts.

The preceding narrative of methods of appraisal work logically leads up to the question: Will these methods that have been adopted in various appraisal undertakings stand the test of the Courts? After all, the final seal of approval must be stamped on a method by the highest Courts before it can be said to be a definitely fixed and determined principle for general use in valuation.

In a careful perusal of many papers on this subject, quotations from judicial decisions will be noted which are literally correct as far as they go, but which are incomplete and often very misleading; and often such incomplete quotations are presented as to convey an entirely wrong impression of the full decision. In order that no such charge may lie against this paper, the quotations given are full enough to indicate clearly the intent of the Court, even at the expense of undue length.

An examination of all Federal and Supreme Court cases which bear on the subject of property valuation has been made, and quotations at length from some of the older cases, establishing precedent, together with citations to more recent decisions, are submitted. It is believed that the points of principle and method, in so far as they have been determined by the highest Courts, are quite fully set forth.

A study of the complete methods of the railroad valuation in Michigan, in connection with these decisions, discloses the fact that they comply with the requirements of the earlier cases, that all matters affecting value be taken into consideration, and that in the more recent decisions the detailed methods adopted in the Cooley physical appraisal have been sustained as to very many points. In no case have any of such methods been unfavorably criticized, and, while at this date the Supreme Court has not squarely passed on the propriety of any method for securing non-physical or intangible values, it has fully sustained the general position of Professor Adams in several important

points. In addition to the complete examination of Federal cases, certain very interesting and valuable State cases have been examined, and some of them are quoted.

These cases involve both matters of taxation and rate-making. They cover railroads, water-works, gas-works, and other classes of public service corporations, and clearly demonstrate the fact that any analysis of the subject of property valuations must include all classes of corporations. Rate-making and taxation in themselves are entirely separate and distinct from valuation, which is a necessary preliminary step in either undertaking. For this reason all references which are not of special interest in the valuation part of the problem are omitted.

The case of Smyth *vs.* Ames (169 U. S., 466) was an action to question the constitutionality of a statute of Nebraska establishing rates. It is of great interest, and, based on the ruling of the Court in this case, the appraiser in Washington and the appraisers in Nebraska have undertaken to secure first cost as an element of value. The decision holds that:

(1) A railroad corporation is a person within the meaning of the fourteenth amendment.

(2) A State enactment establishing rates that will not admit the carrier to earn such compensation as would be just to it and to the public, would deprive such carrier of its property and would be repugnant to the fourteenth amendment.

(3) Rates established by a State cannot be so conclusively determined by the legislature that they cannot become the subject of judicial inquiry.

The reasonableness of rates prescribed by a State for intra-state business must be determined without reference to the interstate business done by the carrier or the profits derived from that business.

This paper is not concerned with the question of rates, which is discussed at length in this decision. It is, however, of special interest to note what the Court says in regard to the relation of the corporations to the people, and to elements of value.

"A railroad is a public highway, and none the less so because constructed and maintained through the agency of a corporation deriving its existence and powers from the State. Such a corporation was created for public purposes. It performs a function of the State. Its

authority to exercise the right of eminent domain and to charge tolls was given primarily for the benefit of the public. It is under governmental control, though such control must be exercised with due regard to the constitutional guaranties for the protection of its property. * * * It cannot therefore be admitted that a railroad corporation maintaining a highway under the authority of the State may fix its rates with a view solely to its own interests and ignore the rights of the public. But the rights of the public would be ignored if rates for the transportation of persons or property on a railroad are exacted without reference to the fair value of the property used for the public, or the fair value of the services rendered, but in order simply that the corporation may meet operating expenses, pay the interest on its obligations, and declare a dividend to stockholders.

"If a railroad corporation has bonded its property for an amount that exceeds its fair value, or if its capitalization is largely fictitious, it may not impose upon the public the burden of such increased rates as may be required for the purpose of realizing profits upon such excessive valuation or fictitious capitalization, and the apparent value of the property and franchises used by a corporation, as represented by its stocks, bonds, and obligations, is not alone to be considered when determining the rates that may reasonably be charged."

(The Court here quotes 164 U. S., 578, Covington and Lexington Turnpike *vs.* Sanford.)

"A corporation maintaining a public highway, although it owns the property it employs for accomplishing public objects, must be held to have accepted its rights, privileges, and franchises subject to the condition that the government creating it, or the government within whose limits it conducts its business, may by legislation protect the people against unreasonable charges for the services rendered by it. It cannot be assumed that any railroad corporation, accepting franchises, rights, and privileges at the hands of the public, ever supposed that it acquired, or that it was intended to grant to it, the power to construct and maintain a public highway simply for its benefit, without regard to the rights of the public. But it is equally true that the corporation performing such public services, and the people interested in its financial affairs have rights that may not be invaded by legislative enactment in disregard of the fundamental guaranty for the protection of property. The corporation may not be required to use its property for the benefit of the public without receiving just compensation for the services rendered by it. How such compensation may be ascertained, and what are the necessary elements in such inquiry, will always be an embarrassing question.

"We hold, however, that the basis of all calculations as to the reasonableness of rates to be charged by a corporation maintaining

a highway under legislative sanction must be the fair value of the property being used by it for the convenience of the public. And in order to ascertain that value the original cost of construction, the amount expended in permanent improvements, the amount and market value of its bonds and stocks, the present as compared with the original cost of construction, the probable earning capacity of the property under particular rates established by the statute, the sum required to meet operating expenses, are all matters for consideration, and are to be given such weight as may be just and right in each case. We do not say that there may not be other matters to be regarded in estimating the value of the property. What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public highway than the services rendered by it are reasonably worth."

The body of this decision is quoted at length to show:

First. That the Court reiterates the relation of the people to the corporation, as defined by Covington and Lexington Turnpike Road *vs.* Sanford (164 U. S., 578) and by Stone *vs.* Farmers' Loan and Trust Company (116 U. S., 307).

Second. That the basis for computing a fair rate is the fair value of the property, which must be arrived at by a computation or series of computations taking into account many different factors.

Third. That while the Court mentions certain things that may serve as indices of value, which are to be taken into account and given due weight, the Court does not outline or define any method of arriving at a value, but does recognize it as an embarrassing question.

Fourth. That no such stress has been laid by the Court on original cost as has been construed by some appraisers.

The principles enunciated in Smyth *vs.* Ames are reiterated by the Court in San Diego Land Company *vs.* National City (174 U. S., 739), with the further ruling:

"The contention of the appellant in the present case is that, in ascertaining what are just rates, the Court should take into consideration the cost of its plant; the cost per annum of operating the plant, including interest paid on money borrowed and reasonably necessary to be used in constructing the same; the annual depreciation of the plant from natural causes resulting from its use; and a fair

profit to the Company over and above such charges for its services in supplying the water to consumers, either by way of interest on the money it has expended for the public use, or upon some other fair and equitable basis. Undoubtedly, all these matters ought to be taken into consideration and such weight given them, when rates are being fixed, as under all the circumstances will be just to the company and to the public. The basis of calculation suggested by the appellant is, however, defective in not requiring the real value of the property and the fair value in themselves of the services rendered to be taken into consideration. What the company is entitled to demand, in order that it may have just compensation, is a fair return upon the reasonable value of the property at the time it is being used for the public. The property may have cost more than it ought to have cost, and its outstanding bonds for money borrowed, and which went into the plant, may be in excess of the real value of the property. So that it cannot be said that the amount of such bonds should in every case control the question of rates, although it may be an element in the inquiry as to what is, all the circumstances considered, just to both the company and the public."

In the case of Columbus Southern Railway *vs.* Wright (151 U. S., 479), the Court quotes approvingly from Franklin Company *vs.* Railroad (12 Lea (Tenn.), 521-537-538-539), and shows that the doctrine quoted had already been enunciated by the Supreme Court in the State Railroad Tax Cases (92 U. S., 575-607). The Court quotes as follows:

"The property of a railroad company for purposes of taxation consists of its realty, its local personalty, its rolling stock, its choses in action, and its franchises. The franchise is a privilege conferred by the charter of incorporation, namely the right to exercise all the powers granted in the mode prescribed for the purpose of profit. It is a unit not confined to any one county in which it may be exercised.

* * * * * * *

"Obviously, after ascertaining the value of the entire franchise in the State as a unit, no more approximate or just division of this value can be made for purposes of taxation than to allot it among the counties through which the track runs in proportion of the entire length of track in the county to the entire length of track in the State. * * *

"The roadway itself of a railroad depends for its value upon the traffic of the company and not merely upon the narrow strip of land appropriated for the use of the road, and the bars and cross-ties thereon. The value of a roadway at any given time is not the original cost, nor, *a fortiori*, its ultimate cost after years of expenditure in repairs and improvements. On the other hand, its value cannot be determined by ascertaining the value of the land included in the roadway assessed at

the market price of adjacent lands, and adding the value of the crossties, rails, and spikes. The value of land depends largely upon the use to which it is put and the character of the improvements upon it."

The mileage basis of apportionment is sustained in the following and other cases:

State Railroad Tax Cases.....92 U. S., 608
Delaware Railroad Tax Case.....18 Wall., 206
Erie Railway *vs.* Pennsylvania.....21 Wall., 492
Western Union Telegraph Company *vs.* Mass..125 U. S., 530
Pullman Palace Car Company *vs.* Pennsylvania..141 U. S., 18
Maine *vs.* Grand Trunk Railway.....142 U. S., 217
Pittsburg, Cincinnati, Chicago, and St. Louis Railway *vs.* Backus.....154 U. S., 430

Therefore this basis of division of values between territorial units appears to be well established by precedent. This is in a measure unfortunate, as certain classes of property cannot be apportioned equitably in this way, unless the value of a railroad be determined, and then that value allocated between different territorial units in proportion to mileage, without any regard to the location of any structure or series of structures in any State or county, the track-mileage basis must be looked upon as a method of apportionment which is subject to modification or which will lead to error.

In an Indiana tax case, Cleveland, Cincinnati, Chicago, and St. Louis Railway *vs.* Backus (154 U. S., 444), the late Justice Brewer, of the Supreme Court, in handing down the judgment, said:

"The true value of a line of railroad is something more than an aggregation of the values of the separate parts of it, operated separately. It is the aggregate of those values plus that arising from a connected operation of the whole, and each part of the road contributes not merely the value arising from its independent operation, but its mileage proportion of that flowing from a continuous and connected operation of the whole. * * * The value of property results from the use to which it is put, and varies with the profitableness of that use, past, present and prospective, actual and anticipated. There is no pecuniary value outside that which results from such use. * * *

"In the nature of things it is practically impossible, at least in respect to railroad property, to divide its value and determine how much is caused by one use to which it is put and how much by another. Take the case before us, it is impossible to disintegrate the

value of that portion of the road within the State of Indiana and determine how much of that value springs from its use in doing interstate business and how much from its use in doing business wholly within the State. An attempt to do so would be entering upon a mere field of uncertainty and speculation."

In the Michigan cases, the principal one being Michigan Central Railroad *vs.* Powers (201 U. S., 245), the question of method of valuation was not passed on by the Courts for the reason that, after the evidence was in, and during the argument, counsel for the railroad admitted that the Cooley valuation was as correct a figure as it was possible to secure under then existing conditions, methods and rates of taxation being the issue.

It is thus seen that the Supreme Court of the United States was not, in any of the earlier cases, required to pass squarely on the propriety of any method of arriving at a "fair value," and consequently had not, prior to 1909, defined any hard-and-fast rules of procedure in determining such value. The Circuit Courts have passed on kindred questions in a few cases, among which San Diego Land and Town Company *vs.* National City (74 Fed., 83), and San Diego Land and Town Company *vs.* Jasper (110 Fed., 714) hold as above, and cite most of the cases referred to. In the latter case the Court says:

"The actual value of such property obviously depends upon a variety of considerations—among them the actual and prospective number of consumers—and is no more unchangeable than the value of any other kind of property."

As an illustration, there is cited the effect of a year's drouth on an irrigation plant as temporarily affecting the value of property.

In the case of Cotting *vs.* Kansas City Stock Yards (82 Fed., 839) the Circuit Court touches on one very interesting argument, in the light of some of the methods of valuation advocated by railway managers and some of the criticisms of recent valuation work.

"Different methods of estimating the value of property may properly be employed when it is valued for different purposes. When a valuation is placed on property which has become affected by a public use, for the purpose of ascertaining whether the maximum rate of compensation fixed by law for its use is reasonable or otherwise, it is obvious that the income derived therefrom by the owner before it was subjected to legislative control cannot always be accepted as a

proper test of value because the compensation which the owner charged for its use may have been excessive and unreasonable. Again, when property has been capitalized by issuing stock, neither the market value nor the par value of the stock can be accepted in all cases as a proper criterion of value, because the stock may not represent the money actually invested, and furthermore because the property may have been capitalized mainly with reference to its income producing capacity, on the assumption that it is ordinary private property which the owner may use as he thinks proper without being subject to legislative control. On the other hand, however, when property is valued for the purpose last stated, it is clear that the owner thereof is entitled to the benefit of any appreciation in value above the original cost and the cost of improvements, which is due to what may be termed natural causes. If improvements made in the vicinity of the property, the growth of city or town where it is located, the building of railroads, the development of the surrounding country and other like causes, give property an increased value, the owner cannot be deprived of such income by legislative action which prevents him from realizing an income commensurate with the enhanced value of his property."

The language of the late Judge Brewer, sitting as one of the circuit judges in the case of National Water-Works Company *vs.* Kansas City (62 Fed., 853), is definite as to the necessity of taking into account some elements of intangible value, and is here quoted as giving the views of this eminent jurist:

"The difficult question, however, still remains; and that is, what is the 'fair and equitable value,' which by the statute and ordinance the city is to pay for the water-works? * * * We are not satisfied that either method, by itself, will show that which under all the circumstances can be adjudged the 'fair and equitable value.'

"Capitalization of earnings will not, because that implies continuance of earnings, and a continuance of earnings rests upon a franchise to operate the water-works. The original cost of construction cannot control, for original cost and present value are not equivalent terms. Nor would the mere cost of reproducing the water-works plant be a fair test, because that does not take into account the value which flows from the established connections between the pipes and buildings of the city. * * * A complete system of water-works, such as the company has, without a single connection between the pipes in the streets and the buildings of the city would be a property of much less value than the system connected as it is with so many buildings and earning, in consequence thereof, the money which it does earn. The fact that it is a system in operation, not only with a capacity to supply the city but actually supplying many buildings, in the city—

not only with a capacity to earn but actually earning—make it true that the 'fair and equitable value' is something in excess of the cost of reproduction."

The foregoing authorities cover practically all the older cases in the Federal Courts. These cases have been examined, and such of the subject matter has been quoted as would show the conclusions of the Courts as to what constitute the various elements of true value. The latest Federal decision bearing on the subject, and in many ways the most replete with argument, is the case of Consolidated Gas Company *vs.* City of New York (157 Fed., p. 849), which was decided in December, 1907.

In this case the valuation was determined by the master:

1.—A valuation of tangible assets, consisting of real estate, plant, mains, services, meters and miscellaneous equipment, and the property of subsidiary companies, the whole aggregating $63 357 000. Of this an allowance of $3 616 000 was made by the master for working capital, and this entire amount was treated as tangible property.

2.—Finally, an intangible value of $20 000 000 was assigned by him to the franchise and good will.

Objections were raised, as follows:

(*A*) Land values represent no original investment by the Company, do not indicate land especially appropriate for the manufacture of gas, and increase the apparent assets without increasing the earning power.

(*B*) The values of physical property are not original cost, but are cost of reproduction less depreciation.

(*C*) Some of the property cost more than new articles of the same kind at the time of inquiry. Some are of designs not now favored by the scientific and manufacturing world.

The disputed questions involved, as far as tangible property is concerned, were:

1.—Whether the values ascribed to the several enumerated items are based on competent and persuasive evidence.

2.—Whether the method of valuation pursued by the master is in accordance with law.

3.—Whether the items of property are "employed" (in the legal signification of the word) in the production of gas.

The first, a question of fact, is found affirmatively, and the evidence was found to be competent.

The second question is one of law, and, quoting from the cases cited in this paper, the Court holds as follows:

"This method of valuation correct * * * upon reason it seems clear that in solving this equation the plus and minus quantities should be equally considered and appreciation and depreciation treated alike. * * * The value of the investment of any manufacturer, in plant, factory, or goods, or all three, is what his possessions would sell for upon a fair transfer from a willing vendor to a willing buyer, and it can make no difference that such a value is affected by the efforts of himself or others, by whim or fashion, or (what is really the same thing) by the advance of land values in the opinion of the buying public. It is equally immaterial that such value is affected by difficulties of reproduction. If it be true that a pipe line under the New York of 1907 is worth more than was a pipe line under the city of 1827, then the owner thereof owns that value, and that such advance arose wholly or partly from difficulties of duplication created by the city itself is a matter of no moment. Indeed, the causes of either appreciation or depreciation are alike unimportant if the fact of value be conceded or proved; but that ultimate inquiry is oftentimes so difficult that original cost, and reasons for changes in value, become legitimate subjects of investigation as checks upon expert estimates, or bookkeeping, inaccurate and perhaps intentionally misleading. * * *

"The so-called money value of real or personal property is but a conveniently short method of expressing present potential usefulness, and 'investment' becomes meaningless if construed to mean what the thing invested in cost generations ago. Property, whether real or personal, is only valuable when useful. Its usefulness commonly depends on the business purposes to which it is or may be applied. Such business is a living thing, and may flourish or wither, appreciate or depreciate; but, whatever happens, its present usefulness, expressed in financial terms, must be its value. * * * It is not to be inferred that any American government intended when granting a franchise, not only to regulate the business transacted thereunder, and reasonably to limit the profits thereof, but to prevent the valuation of purely private property in the ordinary economic manner, and the property now under consideration is as much private property as are the belongings of any private citizen. Nor can it be inferred that such government intended to deny the application of economic laws to valuation of increments earned or unearned, while insisting on the usual results thereof in the case of equally unearned and possibly unmerited depreciation.

"I think the method of valuation applied by the report to land, plant, mains, services, and meters lawful. To 'working capital, Coke

and Coal Company, and Astoria' the above considerations are not applicable, and these items will be treated separately."

The Court's review of the third question raises no points of special interest as to valuation.

The question as to amount of "working capital" is taken up, and that term is defined as:

"The amount of cash necessary for the safe and convenient transaction of a business, having regard to the owner's ordinary outstandings both payable and receivable, the ordinary condition of his stock, or supplies in hand, the natural risk of his business, and the condition of his credit; and unless these matters, and perhaps others, be looked into, no comparison can be drawn between one business and another, or even between those of the same general nature."

In this instance it is of interest to note that the Court reduced the "working capital" from $3 616 000 to $1 616 000.

Perhaps the most novel and interesting part of this decision is that dealing with the intangible elements of value. The master was unable to separate the two elements, good will and franchise value, but gave their combined value.

"From the testimony I think it apparent that what is here meant by good will is the organization of complainant, long established, and doubtless well manned and equipped. Such organization is clearly of value, because without it neither tangible nor intangible property can be profitably managed. Yet the organization itself is but a method of utilizing that which is invested, it is really dependent for its existence and continuance upon the franchise, without which there can be no useful organization. Tangible property has a certain value entirely apart from franchise or right to continue business, but good will in the sense of the organization for the business of furnishing gas, can have no existence whatever apart or detached from the franchise conferring the necessary privilege. Would any one think of capitalizing good will of this kind and distributing its assumed value in the shape of new shares among stockholders new or old? I think the most ingenious financier could not imagine such a proceeding, and, if this good will be not property capable of such capitalization and distribution, I do not think it property capable of capitalization as against the State.

"Finally, this claim of good will seems to forget that for many years the price and distribution of complainant's gas has been regulated by law. A citizen is entitled to have a clean street before his house because he pays taxes, *inter alia*, for that purpose. He is much more plainly entitled to have complainant's gas in his house because the

company must give it to him if he pays for it. I think it apparent that the conceivable good will of a gas company in this city is about equal to that of the street-cleaning department of the municipal government."

Is a public service corporation entitled to add the value of its franchise to the assets from which a fair return may lawfully be demanded? This question is taken up and discussed exhaustively by the Court (157 Fed., 872 to 879), and while it is clear in reading his judgment that he does not believe it sound doctrine to invest a franchise with value, yet, after citing a large number of cases, he reaches the conclusion that he is "compelled" to consider franchises, not only as property, but as productive and inherently valuable property, and to add their value, if ascertainable, to complainant's capital account before declaring the rate of return.

This case went to the Supreme Court of the United States, where, under the title Willcox *vs.* Consolidated Gas Company (212 U. S., 19), citation is made to many cases in connection with the matter of franchise value. The decision of the Court is:

"The value of real estate and plant is to a considerable extent a matter of opinion, and the same may be said of personal estate when not based upon the actual cost of material and construction. Deterioration of the value of the plant, mains, and pipes is also to some extent based upon opinion. All these matters make questions of value somewhat uncertain."

The Supreme Court permitted the tangible values found by the lower Court to stand. It concurred with the lower Court in that it was not a case for a valuation of good will. It concurred with the lower Court in holding that the company was entitled to the benefit of any increase in tangible values, and that such increases should appear in the appraisal. It did not agree with the Court in the increase of franchise value above that which was capitalized in 1884, with the consent of the State of New York, and reduced the franchise value figure to $7 781 000. On this basis, the estimated return, under the new rate on the valuation of $55 612 435, was 5½%, which rate, in view of all the circumstances, is held to be not confiscatory and to be a not unreasonable return on the investment. The franchise value, as commented on in these cases, is referred to at considerable length in the following pages.

On January 4th, 1909, the case of Knoxville *vs.* Water Company (212 U. S., 1) was decided. This, in some respects, is of greater value to the engineer than any others cited, in its determination of methods. In this the appraisement of the tangible property was made in minute detail, the sum of $10 000 was added for "organization, promotion, etc.," and $60 000 for "going concern."

"The latter sum we understand to be an expression of the added value of the plant as a whole over the sum of the values of its component parts, which is attached to it because it is in active and successful operation and earning a return. We express no opinion as to the propriety of these two items in the valuation of the plant for the purpose for which it was valued in this case, but leave that question to be considered when it necessarily arises. We assume without deciding, that these items were properly added in this case. This valuation was determined by the master by ascertaining what it would cost to reproduce the existing plant as a new plant. The cost of reproduction is one way of ascertaining the present value of a plant like that of a water company, but that test would lead to obviously incorrect results if the cost of reproduction is not diminished by the depreciation which has come from age and use. * * * The cost of reproduction is not always a fair measure of the present value of a plant which has been in use for many years. The items composing the plant depreciate in value from year to year in a varying degree. Some pieces of property, like real estate for instance, depreciate not at all, and sometimes, on the other hand, appreciate. But the reservoirs, the mains, the service pipes, structures upon real estate, stand-pipes, pumps, boilers, meters, tools, and appliances of every kind begin to depreciate with more or less rapidity from the moment of their first use. It is not easy to fix at any given time the amount of depreciation of a plant whose component parts are of different ages with different expectations of life. But it is clear that some substantial allowance for depreciation ought to have been made in this case.

"The company's original case was based upon an elaborate analysis of the cost of construction. To arrive at the present value of the plant large deductions were made on account of the depreciation. This depreciation was divided into complete depreciation and incomplete depreciation. The complete depreciation represented that part of the original plant which through destruction or obsolescence had actually perished as useful property. The incomplete depreciation represented the impairment in value of the parts of the plant which remained in existence and were continued in use. It was urgently contended that in fixing upon the value of the plant upon which the company was entitled to earn a reasonable return, the amounts of complete and incomplete depreciation should be added to the present

value of the surviving parts. The Court refused to approve this method, and we think properly refused. A water plant with all its additions begins to depreciate in value from the moment of its use. Before coming to the question of profit at all the company is entitled to earn a sufficient sum annually to provide not only for current repairs but for making good the depreciation and replacing the parts of the property when they come to the end of their life. The company is not bound to see its property gradually waste, without making provision out of earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that at the end of any given term of years the original investment remains as it was at the beginning. It is not only the right of the company to make such a provision but it is its duty to its bond and stockholders, and, in the case of a public service corporation at least, its plain duty to the public. If a different course were pursued the only method of providing for replacement of property which has ceased to be useful would be the investment of new capital and the issue of new bonds or stock. * * * If, however, a company fails to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purpose of earning a return cannot be enhanced by a consideration of the errors of the management which have been committed in the past."

The Court holds that there was error in only considering the operations of the company for a period of one year, and that this should have extended to enough time to remove danger of abnormal business conditions and observe the effects of certain ordinances.

The decision of the Supreme Court, in the Omaha Water-Works case, decided on May 31st, 1910 (*Supreme Court Reporter,* July 1st, 1910), is of general interest in its discussion of the procedure of appraisers in making a water-works appraisal, and in the distinction drawn between appraisals and arbitrations; but it does not touch on appraisal methods or elements of value, except to discuss "going values." The language of Judge Lurton on this point is as follows:

"The option to purchase excluded any value on account of unexpired franchise, but it did not limit the value to the bare bones of the plant, its physical properties, such as its lands, its machinery, its water-pipes or settling reservoirs, nor to what it would take to reproduce each of its physical features. The value, in equity and justice,

must include whatever is contributed by the fact of the connection of the items making a complete and operating plant.

"The difference between a dead plant and a live one is a real value, and is independent of any franchise to go on, or any mere good will as between such a plant and its customers. That kind of good will, as suggested in Willcox *vs.* Consolidated Gas Company (212 U. S., 19), is of little or no commercial value when the business is, as here, a natural monopoly, with which the customer must deal, whether he will or not. That there is a difference between even the cost of duplication, less depreciation, of the elements making up the water company plant and the commercial value of the business as a going concern is evident. Such an allowance was upheld in National Water Works Company *vs.* Kansas City (62 Fed., 853), where the opinion was by Mr. Justice Brewer. [This decision is quoted in the foregoing pages.] We can add nothing to the reasoning of the learned Justice, and shall not try to. That case has been approved and followed in Gloucester Water Supply Company *vs.* Gloucester (179 Mass., 365, and 60 N. E., 977), and Norwich Gas and Electric Company *vs.* Norwich (76 Conn., 565). No such question was considered in Knoxville Water Company (212 U. S., 1) or in Willcox *vs.* Consolidated Gas Company (212 U. S., 19). Both cases were rate cases and did not concern the ascertainment of value under contracts of sale."

The writer does not read into the language of this decision an approval of a separate element of value to be called "going concern value" or "going value" in addition to other non-physical values, but rather a recognition of the fact that certain non-physical elements of value, by whatever name they may be called, must be taken into account in arriving at the fair and equitable final figure of value of a live and operating concern for the purpose of carrying out a contract of sale.

It appears to be doubtful whether the Court can be construed as approving such an element of value in rate cases.

It thus appears that the United States Courts have laid down a few rules, which may be regarded as fixed and definite and must be followed, but that many important questions have not yet been decided. The value to be determined must be a "fair value" of the property being used for the convenience of the public. The par value of stocks and bonds may not alone be considered (although it may be considered), the market value of stocks and bonds, original cost plus cost of additions, the probable earning capacity, the cost of reproduction, depreciation, appreciation, all these, and any others that will

throw light on the "fair value" must be taken into account and given the weight to which they are entitled. Any fictitious book values due to over-issues of stock and bonds are to be given no weight, but the appraisal must give the fair value, in the light of all the facts, of the property in actual use at the time of the appraisal.

There are several decisions of the State Supreme Courts which discuss these subjects, but an examination of a number of these gives practically nothing more, in the way of definite conclusions as to method, than has been cited. Perhaps the most complete and painstaking consideration of appraisal problems by any Court was that given by Judge Savage of the Supreme Court of Maine (97 Maine, 185, and 99 Maine, 371). These were neither rate cases nor taxation cases, but proceedings under statute to require from the Court instructions to a board of appraisers appointed to value the plants. In the later or Brunswick case, Judge Savage elucidates a number of points left not altogether clear in the Waterville case. The Brunswick decision contains some interesting views on "going value," and the Court's remarks on the general difficulties in making rules for an appraisement are exactly to the point:

"There are many difficulties, if not dangers, in attempting to formulate rules which are to be applied to facts not yet ascertained. While it may be easy enough to state rules in the abstract, it is much more satisfactory in an opinion of the court, to express them in terms which are applicable to the facts in the precise case in hand. * * * It must be always understood that our answers to these questions are intended to be given only in the most general and comprehensive terms, which may, or may not, be found to be fitted to the facts which may subsequently be developed. No other course would be wise or safe. * * * A public service property may or may not have a value independent of the amount of rates, which for the time being may be changed. A public service company may, under some circumstances, be required to perform its services at rates prohibitive of a fair return to its stockholders, considering their property as an investment merely. * * *

"Now, what is the property which the district has taken by power of eminent domain? In the first place it is a structure, pure and simple, consisting of pipes, pumps, engines, land rights, and water rights. As a structure, it has value independent of any use, or right to use, where it is, a value probably much less than it cost, unless it can be used where it is, that is, unless there is a right to use it. Nevertheless, it has value as a structure. But, more than this, it is a struc-

ture in actual use, a use remunerative to some extent. It has customers, it is actually engaged in business, it is a going concern. The value of the structure is enhanced by the fact that it is used in, and in fact is essential to, a going concern business. We speak sometimes of a going concern value as if it is, or could be, separate and distinct from structure value—so much for structure and so much for going concern. But this is not an accurate statement. The going concern part of it has no existence except as a characteristic of the structure. If no structure, no going concern. If a structure in use, it is a structure whose value is affected by the fact that it is in use. There is only one value. It is the value of the structure as being used. That is all there is of it."

The Court then argues that, as the structure is being used under authority and by virtue of franchises, it is more valuable. The franchise, however, is limited; other and competing franchises may be granted; a franchise may exist entirely independent of a structure. He holds that the structure is more valuable with the franchise.

"It is a structure in actual use, and with a right on the part of the owner to use it and to charge reasonable rates to customers for services rendered. It is threefold in discussion but it is single in substance."

This case is largely taken up with a discussion of the reasonableness of rates which furnish a basis for the estimate of value. There is no specific attempt to describe methods of procedure. That is left to the appraisers. These two Maine Cases, together with a valuable paper* thereon by Leonard Metcalf, M. Am. Soc. C. E., constitute an extremely valuable addition to the literature of appraisements.

It is clear, from a study of all the cases referred to in this paper, that the Courts have laid down a line of precedent which is equitable and just, that the interests of both public and corporations will be safeguarded, and that the likelihood of any unfair or improper valuations passing the scrutiny of the Supreme Court is but remote.

Physical Values and Methods for Their Determination.

All the foregoing narrative of methods adopted in recent valuations, review of judicial opinions, and comment on the expressed opinions of various engineers and railway officials, is presented as being proper and necessary to support the contention that the Michigan

* *Transactions*, Am. Soc. C. E., Vol. LXIV, p. 1.

valuation, while not the first appraisal work, was the first valuation work of large magnitude undertaken by any State; that it was a work which established many precedents; and that the complete discussion of methods and principles in connection with and following this appraisal has given it probably a greater general value than any similar undertaking. The Wisconsin work, which immediately followed that of Michigan, was along lines similar to those of the Michigan physical valuation, and carried the work forward, adding to and strengthening certain of its features. Without any impropriety, it may be claimed that these two appraisals have laid down the general lines on which this class of engineering effort will be largely directed in the future.

It is desirable, in closing this paper, to indicate such general methods of procedure in valuation practice as may be said to have been thoroughly established by precedent, and to present such argument as will support the contention that such methods are proper.

The fact has been emphasized, again and again, by every writer on the subject, that problems of this class are not capable of exact mathematical solution; that, no matter how much care may be exercised in the execution of the work, the result is tempered by the personal judgment of the men engaged on it, and that only when it is executed by men of experience, sound judgment, and high moral worth can it have a definite, final, and just result.

This feature of appraisal work cannot be too strongly emphasized. The value of the work depends on the character of the men doing it, their experience in design, construction, and operation of properties, and their absolute fairness and freedom from prejudice.

That there will be many large valuations undertaken in the near future, there appears to be no doubt. These valuations will be made as a necessary preliminary to three classes of corporate control: rate-making, taxation, and the regulation of capitalization.

The Courts hold that the value must be "the fair value of the property used for the public," and that the corporation:

"may not impose upon the public the burden of such increased rates as may be required for the purpose of realizing profits upon [such] excessive valuation or fictitious capitalization." (Smyth *vs.* Ames.)

This language is repeated, again and again, so that it is clear that any valuation, to be sustained by the Courts, should:

1.—Be based on a careful study and analysis of all the information applicable to the case in hand; and

2.—That it must separate the various elements so that every step of the work may be reviewed and supported.

Public interest demands that, in any valuation, certain figures shall appear which shall show the amount of *bona fide* capital actually existing in the property at the date of appraisal.

The fact that a given amount of money was invested in building a railroad in 1880, and that certain other sums were spent for additions in subsequent years, does not necessarily indicate that these amounts of capital will still be found in the property in 1910.

The removal of timber from surrounding lands, the destruction of industries and the removal of tracks leading thereto, the destruction of equipment and facilities, the depreciation in value of adjacent property, along with wear and tear, and obsolescence, have gone to effect the destruction or loss of capital on many Michigan railroads. The case in 212 U. S., 1, clearly directs that the valuation must not take into account this destroyed capital, but must return a "fair value of the property as it is."

On the other hand, the amount of money actually spent in producing a given property in the past may be far below the present value. The appreciation of value of lands by reason of development of cities and growth of industries, the increase in cost of the materials entering its construction, and many other causes, may lead to an appreciation of the value of the property, and this appreciation should appear in the valuation and the company be entitled to the benefit of it. It is in the nature of an increase of the investment, and should appear as capital.

It is clear that there are two classes of elements of value in the final value of a public service property: those which are physical, and those which are intangible. There are various of the physical elements of value which are not material or susceptible of inventory, but which, nevertheless, attach themselves to the physical property, are capable of determination, within reasonable limits of certainty, and should be taken into account and computed as physical property.

In the subsequent discussion of physical and intangible values, it is

attempted to differentiate between such elements as should attach to the physical value, or capital remaining in the plant, and the purely intangible or franchise values.

It is contended by the writer:

That the Physical Value, or present value of the physical property, should fairly represent the actual capital invested in the property at the date of appraisal; that it should be made up of the sum of the various elements which constitute the cost of reproducing the property together with any appreciation which may have been added to any of them, less all depreciation.

That the Non-Physical Value is the difference between the "fair value" as defined by the Courts, or the reasonable value of the property as a business or producing property, and the physical value, or actual present worth; and that the only proper method for determining such values involves a study of income accounts.

This Non-Physical Value may be: positive, or a value in excess of the physical property, or negative, or less than the physical value. In the case of a property having a negative intangible value, a deduction should be made from the physical value.

It is further contended that, in making the physical appraisal, the purpose of the appraisal should not be permitted to modify the figures. The resultant figure should be the same, whether it is to be used as a basis for assessment, rate-making, or limitation of capitalization. It should be an engineering estimate of the amount of *bona fide* capital still remaining in the property, or of the complete cost of reproduction under existing conditions, less depreciation. This figure is definite, within reasonable limits, and it cannot be conceded that it is permissible to vary it, submitting one result as a physical value for taxation, and another and different result as a present physical valuation for rate-making.

There may be some question as to the propriety of using non-physical values for certain ultimate ends; in fact, the Supreme Court, in the Omaha and Knoxville water cases, clearly indicates that they must not be used for certain purposes; but, in any case, to furnish information, this element of value should be determined, and, as in the case of physical values, it should be an unchangeable figure* and should represent the difference between the worth of the actual physical prop-

* Unchangeable only for the period under consideration and as regards the purpose of the appraisal. This value varies from year to year, depending on business conditions and on earnings of the company.

erty and the final business value of the property considered as an earning proposition.

It is not necessary to go minutely into detail as to the various steps to be taken in making the appraisal of physical property. Each appraisal will offer some problems peculiar to itself, and no general set of rules can be laid down which will be applicable to all cases. It is deemed sufficient to call attention to general matters of major importance and to refer to some points which have not been mentioned in the preceding narrative, omitting argument in the case of such as have there been fully discussed.

The distinction should be kept in mind that any element of value which belongs to the property by reason of its physical existence is classed as an element of physical value. The property is considered as an operating property in the sense that it is reproduced complete, ready to operate; and any expense, or any element of value needed to complete it, is an element of the physical value, but any value arising as a result of surplus earning power, any good-will value, going-concern value, or value due to established business, strategic location, favorable traffic arrangements, etc., should be considered as intangible values.

The valuation of physical property is naturally divided into four parts:

I.—The preliminary study,
II.—The field inspection,
III.—The computation,
IV.—The preparation of the final figure.

I.—The Preliminary Study.

The preliminary steps should include a general examination of the property, a study of its corporate history, an examination of its records, maps and profiles, and the preparation of an inventory of its property.

The work in Wisconsin and Minnesota was done in co-operation with the railroad companies, who prepared (generally, but not in every case) their own inventories on forms adopted by the appraiser. In Michigan, all this information was secured by the appraiser. There can certainly be no valid objection to the use of information compiled by the companies, whose familiarity with their own records and prop-

erty would enable them to supply lists which under all ordinary conditions would be more complete and up-to-date than if made up by men having no special knowledge of the property.

The chief difficulty encountered in making an inventory from recorded data lies in the fact that very few sets of records are corrected to date, and many additions and erasures will of necessity have to be made in the field.

In making a field inspection, it is of great assistance to be able to refer to maps of large yards, to profiles, to standard plans, and to drawings of the principal structures, so that the investigation of office records should include a careful examination of the maps of principal terminals, with a view to securing such as will simplify the field inspection. The investigation should be extended to cover a study, not only of the engineering office data, but also statistical data to be derived from the records of the auditor, superintendent, and superintendent of motive power, and should cover earnings, operating expenses, car and locomotive mileage, and such other data as will facilitate the distribution of such elements of value as are not localized, together with such other statistics as will furnish a thorough knowledge of the property and its operations.

It has been claimed by the appraiser in Washington—and the view is also held by the Commissioner of Railroads in Nebraska—that original cost is essential, in view of the Supreme Court's decision, particularly in Smyth *vs.* Ames. The writer cannot accept the correctness of this position. It would appear that the language of the Court should be construed to mean that original cost, where ascertainable, is a proper matter to take into account, along with many other things, but it can hardly be considered mandatory.

In the case of a property only recently built, in which the records are complete and the engineering and construction files are available, it may not be specially difficult to determine cost, but in the case of any of the large railway systems of the United States, which are made up of the consolidation of many different roads, some of them built many years ago, some of them having gone through many changes of management, reorganization, and earlier consolidation, it is practically impossible to secure either the old financial books or the old construction records, and without these complete records it would appear to be an utter impossibility to secure the primary cost. Primary cost is but

the first step. The work of building up, by securing the amount of additions and betterments that have been made from year to year, is one of appalling magnitude and of utter uncertainty and conjecture. Keeping in mind that, prior to July 1st, 1907, the railroad companies of the country did not have a system of uniform accounting, and that additions to property were charged to operating expenses to the extent of hundreds of millions of dollars; that policies were different on different roads, and under different managements of the same road, and that the accounting methods were determined by the policy of the road or management; and the further fact that the distribution of ordinary railroad accounts may be extremely reliable on one road and abounding with errors on another; it will be seen that any attempt to depend on the auditor's office for anything approximating a complete statement of cost would lead into a maze of figures which would be confusing, unreliable, and incapable of proof.

Therefore, it is the writer's conclusion that, beyond such figures on recent construction, or records of cost of such special structures as are matters of particular record, it is not advisable to attempt to secure complete data as to the cost to date of a railroad. In the Michigan appraisal, original cost was secured in the case of many structures, notably the Port Huron Tunnel, and it is by no means argued that original cost should not be considered, or investigated, but it is held that such an undertaking as to secure, from the financial books of the company, an accurate or reliable statement of construction cost, plus additions and betterments, less property destroyed, of the Michigan Central Railroad, for example, would be absolutely an impossibility, particularly if the work was to be undertaken, as in the Washington appraisal, by men who were utter strangers to the property. The admission of the appraiser of Washington, that, except for a few gaps, the information was complete, is fatal, as the gaps must needs be filled by estimates, and it would appear to be better to depend on estimated figures throughout than to use what purported to be actual costs on part and estimates on the remainder.

If original cost is essential, it is hard to get away from accepting the book values of the companies, as these, objectionable as they may be, from the viewpoint of the public, are just as apt to be as near the actual truth as any statement made up by strangers from an examination of old records covering many years of operation.

II.—The Field Inspection.

The field inspection, to be of the greatest value, should be made by civil or mechanical engineers of long experience, preferably by men who have had charge of their respective departments on railroads of considerable extent, or of properties similar to that under investigation. The writer is of the opinion that in this particular phase of the work, the practice adopted in the Michigan appraisal was considerably in advance of more recent valuations. Each particular structure or piece of equipment should be examined and its condition noted; special features should be fully described and careful record made of everything that would tend to affect the value. The argument has been often made that the fixing of a percentage of depreciation by a man in the field is purely arbitrary and amounts to nothing but a guess. In the computing office it is often necessary to check the field figure of depreciation by the use of tables of fixed annual depreciation, but it must be borne in mind that mortality tables of any form are based on a system of averages. The actual depreciation on rail, for instance, varies greatly; the conditions of traffic, curvature, gradient, rolling stock, and various local conditions tend to shorten or lengthen the life, so that the personal opinion of an experienced man on the ground is likely to be much more nearly correct than the arbitrary application of a rule of averages.

The writer has inspected station buildings more than 50 years old, and their condition and adaptability for the service required of them would give them a very high percentage; he is also familiar with buildings less than 10 years old, which, by reason of changed traffic conditions and consequent shifting of business, have become obsolete and have been permitted to depreciate so rapidly that any table average would give too high a result.

In the case of a water-works inspection, so much of the value is included in the system of distribution mains, a form of property which is inaccessible, that much more dependence must be placed on a figure based on age; but there, also, as full investigation as possible should be made, in order to determine to what extent tuberculation or electrolysis has affected the pipes.

A general inspection (made in Minnesota by the appraiser with two assistants) would appear to be an excellent thing as a review of the whole work, but whether such an inspection would be sufficiently

thorough to base thereon a set of final values, would appear to be doubtful.

The inspection in the field, in addition to the placing of a percentage for depreciation, should involve a complete check of the inventory, a correction of all errors, due to the construction of new property or the destruction or removal of old, and a compilation of all information required for a complete, correct, and intelligent appraisal of the physical property by the computing office. Every appraisal is different, and every property offers new problems and diverse conditions. These must be met, and therefore the field inspector must call particular attention to all matters specially affecting the values of the property he is inspecting.

It is impossible to anticipate all these conditions in advance, although the use of carefully prepared blanks and the standardizing of the form in which the data are gathered greatly simplify the work, not only in the office, but in the field.

III.—The Computation.

On the completion of the field work, with all the preliminary data in the office, the computation must proceed, and with this part of the work there are many questions which must be taken up, considered, and definitely answered.

The classification and arrangement of the information as to the property to be valued, the costs and prices of the various materials entering into construction, the making and checking of such tables as may be required for estimating, the computing, checking, filing, indexing, and the various other routine details of work need not be referred to specially, as they must be worked out for each appraisal. The matters of principle that will be met are more important, and, while it would be impossible to mention all that may come up, it may not be amiss to refer to a few.

(a) In making an appraisal of several properties, to what extent shall these properties be grouped or classified?

(b) What unit prices shall be assigned in the estimates of cost of reproduction, and how shall they be determined?

(c) How shall right-of-way and real estate values be ascertained? Shall such elements as appreciation, or any increments due to the purpose for which the land is used, be treated as physical or non-physical values?

(d) What method shall be finally adopted in determining depreciation? What elements shall depreciation be made to cover?

(e) What elements of cost or appreciation shall be treated as parts of the physical property although not capable of inventory, and what shall be treated as non-physical?

(f) Is an allowance for contingencies a proper item to include in an appraisal?

(g) What weight shall be given the matters of adaptability, proper or improper design, and the economics of location?

(h) How shall the values of such property as locomotives, cars, etc., be geographically assigned?

(i) What is the effect upon values of large terminals?

(j) Should an allowance be made by reason of rapid development of the art?

These are not by any means all the perplexing questions that arise; each valuation offers some that are special, but these cover the more important points.

(a) Classification of Properties.—In making an appraisal involving the properties of a large number of companies, such for instance as any of the State railroad appraisals, it becomes evident that there are certain properties which are small, badly run down, and either built to serve a very limited trade or located in a territory which has not developed, and that such properties cannot be compared equitably with the large trunk-line roads, or even with smaller roads in a good territory and doing a good business. Several such properties exist in Michigan in a district which was originally a lumber-producing country, and at the time they were built local conditions were such that prices of timber and labor were far below any cost that it would be reasonable to assume to-day. Whether taxation or rate-making be the ultimate end of the work, it is certain that these carriers are entitled to some classification which will separate them from the more prosperous roads. Many of these roads would not be built to-day under any circumstances, yet their maintenance and continued operation is absolutely essential to the people of the district served by them.

Whether this classification should be undertaken at the time of making the appraisal of physical property, and an attempt be made to classify unit prices, or whether this should be taken up in connection with the intangible values, and solved, as far as the valuation is concerned, by the adoption of such a method as will affect these

physical values by a subtractive or negative non-physical value, or whether the entire matter should be left for the subsequent work of rate-making or assessment, is one which must be determined at the outset of the physical valuation. It may not be left without determination, as the question will be raised in all probability in the form of an attack on the valuation, if it is not considered and a conclusion reached.

It is the writer's opinion that the application of an intangible subtractive value is the proper solution, except in the case of roads which would not to-day be rebuilt. In fixing a uniform price for identically the same labor or material, whether on a small poverty-stricken road or a main trunk line, no serious injustice is done, provided the price fixed is one which, from a strictly engineering standpoint, is a reasonable figure for cost of reproduction. The differences in class are due, not to special differences in cost of physical property, but rather to differences in earning ability on account of good or poor territory served, efficient or inefficient management, or other reasons not connected with the physical structure; hence such differences are reflected in the earnings, and are clearly elements to be adjusted in the non-physical valuation.

(b) Unit Values.—The general reliability of the appraisal rests very largely on the reasonableness and fairness of the various prices which are applied to the different parts of the property in making the estimate of cost of reproduction. These unit prices should be determined before any actual figures are made. They should be made up from the most complete data available, and, before being tabulated, should be carefully reviewed by all the experienced men engaged on the appraisal, in order that no figure which is either too high or too low may be used.

As a basis, the average of either 5 or 10 years should be used in preference to current prices on all such material and equipment as is fairly stable. Rail, and all forms of rail structures, machinery, locomotives, cars, etc., can be reduced to such a unit that averages can be secured which will eliminate the error due to a period of extreme high or low prices.

In the case of such materials as lumber and ties, the price of which has been steadily rising, due to the growing scarcity of the material, a price based upon a long average is unfair to the corporation, and

it would appear to be proper to use current prices. There can be no hard-and-fast rule which will be applicable to all appraisals. The unit prices must be such reasonable figures as can be sustained in Court. Their adoption should not be final until every possible test of their accuracy and reasonableness has been made. When they have been adopted, and such modification made as may be fair for certain territory, on account of local conditions, transportation facilities, or other consideration which may affect them, the adopted figures should be applied to all property alike. The use of different unit figures for different roads in the same territory is highly undesirable, and should be avoided.

(*c*) *Right of Way and Real Estate.*—The valuation work which has been accomplished during the past decade, and the study of values for taxation and rate-making, have brought into prominence the perplexing features of land values as applied to corporation property. It is comparatively simple to fix within very close limits the reproduction cost of tracks, bridges, locomotives, or any of the other elements of physical structure. Not so with the land. A few years' development may change farm land right of way into city right of way, surrounded by factories, or it may change desirable residential property adjacent to a road into slums.

In view of the clear language of the Court in 82 Fed., 839, and 157 Fed., 849, it is evident that any valuation which does not take into account the appreciation or depreciation of land values cannot be sustained. There can be no serious objection to the doctrine that the property of a corporation generally increases or decreases in value in the same proportion as adjacent property, and it must therefore be admitted that a value based on the sale value of adjacent lands is a reasonable one and must stand. This reasoning, of course, will be subject to exceptions, in the case of terminal properties, docks and water-front properties, and right of way in large cities, but it is believed to be sound when applied to right of way in the country and in small towns and cities.

The next question to be determined is whether the increment of value due to the use of the land is a proper one. It would appear that in the use of land for water-works, gas-works, street-car barns, or other isolated tracts of land used for corporation purposes, this increment would be much less than in the case of a steam or inter-

urban railroad, the holdings of which form a continuous and unbroken strip; and, in the case of street railroads, water-works, and like properties, it would be indeed difficult to compute and afterward sustain any considerable increment.

In the case of railway properties, however, it is quite evident that the following facts can be sustained: The actual cost of property purchased for railway purposes will range from two and one-half to five times the selling price of similar and adjacent property used for other purposes. While the actual percentage will vary somewhat, as between land in cities and in the country, and as between fully settled districts well served by roads and sparsely populated regions, yet the difference is very marked, and is capable of determination by an examination of the public records.

This difference can be determined either by a comparison of railway purchases and other transfers, as was done in the later studies in Michigan and in Wisconsin, or by extending the investigation to include assessed valuations, and using the averages, as was done in the work of Mr. Morgan in Minnesota.

In establishing figures for use in a valuation, it would appear to be better to base them on an analysis of actual transfers than to undertake to fix values by any methods of examination and personal appraisal. Enough instances of the wide divergence of expert opinion have been cited to show conclusively that such a method, applied to the thousands of acres of a large corporation, may lead to serious error.

A single attorney or real estate man who has had experience in abstracting and conveyancing, and who has bought some right of way, can examine the records of an average county the largest city in which has a population of 20 000 or less, abstract all railway transfers for 5 years, locate them on the maps, secure data as to actual selling prices of near-by lands, and, in a comparatively short time, be in position to furnish figures which will establish the relation between sales for railway and other purposes in that county. The work that half a dozen such men could do in 90 days would go very far toward establishing with a fair degree of definiteness the value of the railway purpose increment for the majority of counties in any average State. Of course, such an investigation in the large cities is a matter of much greater labor, and would require sufficient time to make complete

examinations, probably necessitating a special force for such city work.

On every appraisal, the question has been asked, should this railway purpose increment be added to the value of the property? Clearly, yes.

The Supreme Court quotes approvingly from the Tennessee Court, as follows (151 U. S., 479):

"The value of the land depends largely upon the use to which it is put and the character of the improvements upon it."

This is stated again and again. It must be remembered that, for railroad uses, the strip must be continuous; that it must be located so as to permit curves and grades which conform to the requirements of the road; that, no matter what damages may accrue to adjacent property, the road must take its strip; that its use is entirely changed and is a structure placed on it which is capable of vastly greater earnings than the property produced before—all these elements add to the cost of the property when it is acquired for railway purposes, and in the same measure to its value under its new use.

In a new country, where transportation facilities are limited and land cheap, this added increment may be little or nothing, but in a thickly settled State, with many railroads, this element will increase with a good degree of uniformity; while, in terminals, the price rises to almost inconceivable figures. It is capable of being determined, and is clearly an element in the cost of reproduction. The writer holds to the view that it is properly to be placed with the physical values, and that it should not be considered as an intangible element of value.

(*d*) *Depreciation.*—Thus far, this discussion has not dealt at length with the subject of depreciation, and it is not considered essential to the purposes of this paper that it be done. The State appraisals have raised a question as to the propriety of using mortality or life tables as compared with personal inspection and the placing of a percentage based on individual judgment. Either method is subject to error. It is certainly desirable to secure the opinion of the man who inspects a bridge, or building, or locomotive, as to its physical condition. It may be desirable to use the check secured by the fact that the age of the building is known and also the average life of structures of its class.

The result of the Michigan inspection of rolling stock was to sustain fully the rules for valuation issued by the Master Car Builders Association; and clearly, it is not only proper, but extremely desirable, to apply tables to such equipment as freight cars, which are scattered all over the United States, for it would be absolutely impossible to inspect completely those of any road or system. On the other hand, the life of steel rails cannot be determined by any simple table, because the number of car movements, the weight of motive power, the speed of trains, the location (on curves or on heavy grades), and many other conditions affect their life. This also pertains to buildings, locomotives, and other equipment. The character of service rendered, the nature and extent of repairs, and the way in which they have been maintained, add to or take away from any life assigned by tables, so as to render them valueless in many individual instances.

In placing depreciation, allowance should be made, not only for wear and tear due to use, and decay due to the elements, but also to cover that which is due to obsolescence, or the fact that the facility is of an antiquated or inefficient type, and has been superseded in general use by more efficient and economical devices; this may be called commercial depreciation, as distinguished from physical depreciation. The method to be used in placing depreciation is clearly one of the important things that must be determined by each set of appraisers, and, while the writer believes that the use of expectancy tables would greatly facilitate the work in many cases, the data on which to found a complete set of tables and to support them and justify their use are often lacking; therefore, any use of tables should be safeguarded in every possible manner, and personal inspection of fixed property should always be made.

(*e*) *Immaterial Elements of Physical Property.*—There are certain expenses, inseparable from the construction of any public works, which are a necessary and proper part of the cost, and are arranged for in the original financing, but are not capable of identification after the completion of construction work. These expenses are:

(1) Organization,
(2) Legal expenses,
(3) Engineering,
(4) Administration,
(5) General expense.

(1) Organization.—This includes the cost of the original organization of the company, the cost of securing the charter and franchises, arranging the financial plan, and securing the funds for construction.

The latter item is intended to include all salaries and expenses of officials in soliciting and negotiating for funds, the services of trustees, and all other proper expenses which are usual and unavoidable in the process of exploiting a projected enterprise and interesting capital therein. Discount on bonds is not included, and any allowances for "premium," or "bonus," or other cash payment to any party for services in securing funds, which are in excess of legitimate expenses, should receive scant consideration at the hands of appraisers.

(2) Legal Expense.—This is for attorneys and all legal expenses, costs, and fees in the organization and during the construction of the property.

(3) Engineering.—This includes reconnaissance, preliminary and location surveys, supervision of construction, and design and superintendence of special structures. The cost of engineering on some of the more difficult properties becomes a very large sum; on certain small lines it may be comparatively small; and in some cases no engineers have been employed at all; but the items of cost covered by this charge have in every case been expended, even if done under the direction of some superintendent.

(4) Administration.—This comprises the cost of the management during construction—the direction of the enterprise.

(5) General Expense.—This is the cost of the general office organization during the construction period, also numerous minor expenses, not distributable.

It is not possible to build any public service plant without incurring all these expenses to a greater or less degree. They are essential elements of cost, and must go into the value of the plant when completed. It can hardly be argued that cost, which in a large property runs into thousands or hundreds of thousands of dollars, has no value at the commencement of operation, nor does it appear that the value is subject to depreciation as long as the property is an operating plant. The writer holds the view that the line between physical and non-physical elements of value should be drawn as follows:

Any value which attaches to the property by reason of any money expended during the construction is part of the physical property

values; while any value due to the operation of the property which is in excess of the physical value is a non-physical or intangible element. If the correctness of this position be conceded, then all the foregoing items are charges against the physical property, and, as long as it is an operating property, these items of value remain part of the physical property, and the writer contends that they should not be considered as affected by depreciation, as long as the property is a going concern.

Different engineers have included in the appraisal other items which are of a somewhat different nature, and some of which are open to argument; among these are "interest during construction." This item is clearly an allowable one, but serious differences of opinion develop as to a proper amount to allow in making an appraisal.

The corporate history of the Ann Arbor Railroad, in Michigan, shows that it was built in sections of from 25 to 30 miles, and that each section was put into operation as soon as built, so that, while the actual period of construction of the complete property extended over 15 years, no section was under construction much more than one year. This is typical of much of the railroad building of the past, and on such a property the interest charge would be comparatively small.

A proper charge in such a case would clearly not be sufficient in the case of a road several hundred miles in length, through mountains, with tunnels, heavy bridges, and other structures which would extend the actual construction over periods of from 3 to 5 or 6 years, and this is particularly true where the road is a main line or artery, and where local traffic is of minor importance.

The computation of the interest charge is complicated by the fact that interest begins to run as the bonds are taken up, and but a small part of the construction money draws interest during the whole period.

The practice in the State appraisals has been to fix a uniform percentage for all properties. This has had in its favor the argument that it was conservative valuation where taxation is the ultimate end, as the amount was less than one year's interest in every case. It would appear to be more correct to use the corporate history of each company, determine the actual construction periods, and use a rate based on the actual time in each case. This can be fixed with a fair

degree of accuracy, and a reasonable percentage determined, to equalize the varying periods of time on which the interest runs on different parts of construction.

Discount.—Discount on bonds is claimed by certain railroad men as a proper item for consideration. As has been argued elsewhere, this is not a proper charge against capital. It is an adjustment of the interest rate to the market, or an advance payment of interest; and, in the writer's opinion, should under no consideration be allowed.

Working Capital.—Working capital is another item claimed and conceded in some valuations. It is not a part of the "cost of construction." The money provided for working capital at the outset is not a permanent investment, but is rather a temporary loan paid back out of earnings. The writer fails to perceive any possible argument in favor of adding such an item to the permanent value of the property. In making an appraisal, after the physical value is determined, it is usual to set up a statement of stores, supplies, fuel, and cash on hand, and working capital is certainly shown by the current balance sheet, in the form of cash or accounts receivable. It would appear to have no place in a physical appraisal. Although the items of cash, stores, and supplies were shown in the Michigan appraisal, they did not appear as part of the physical value, nor were they taken into account in computing intangible value, but, being taxable property, they were reported separately.

(*f*) *Contingencies.*—The use of a percentage for contingencies in the appraisal in Michigan was bitterly contested by the railroads as improper and excessive. In Michigan 10% was used, in Wisconsin 5½%, and in Minnesota 5 per cent.

Subsequent work in Michigan has demonstrated that the use of as high a figure as 10% was fully justified; and the probability is that the latest Michigan appraisal did not eliminate omissions, inaccuracies of description, and excess cost of construction due to difficulties, to such an extent as to justify much reduction in the percentage.

In making an appraisal, the percentage to be applied to cover contingencies is a proper matter for consideration, and in some cases conditions might well be such that even a smaller allowance than that fixed in Minnesota would be proper, but such cases would doubtless be the exception. The writer believes it to be proper practice to add liberally for the contingency item. The strongest argument against

it is that it is incapable of being described and located definitely, and is difficult of exact proof. Therefore it has been claimed that it partakes of the nature of a non-physical element, and that if there be any value over and above the physical property value, it will appear with other non-physical elements reflected in the earnings, and may be properly included in the intangible value if such exists. This argument does not appeal to the writer as being final, and he would advocate the use of such a percentage of physical values as appears proper in each appraisal to cover the error due to the extreme difficulty of securing an exact inventory and construction history of the properties.

(*g*) *Design.*—Among the matters which were considered in the Michigan work was that of adaptability, or the economical questions of location, design, and construction. It is possible that in some properties, such as water, gas or electric companies, the efficiency of the plant may be very greatly affected by faulty design, uneconomical arrangement, improper construction, and to such an extent that any cost of reproduction, less any ordinary depreciation, would be greatly in error without further allowance. This may also be true of railroads. Excessive curvature and gradients greatly decrease the tonnage hauled by a given power, without decreasing the cost per train-mile.

It is extremely difficult to treat this as a physical element. It is impossible to reduce it to terms of dollars and cents by any usual or customary methods. It is impossible to separate it from any one of half a dozen other items that may be brought up. It opens the door to endless speculation as to what might or might not take place under somewhat different conditions. For these reasons, it was treated in the Michigan appraisal as a non-physical element of value and dismissed from all consideration in the physical appraisal. This was clearly proper, and the subject is only referred to here for the purpose of making clear that it was fully studied and a definite conclusion reached.

Adaptation.—In the sense that this term is used by Mr. Williams and Mr. Morgan, the appreciation or solidification of roadbed was considered in the Michigan work, but given no place in the appraisal. This is a very proper item to consider, but it would appear to be better to include it directly with the roadbed item in the physical appraisal

as appreciation or solidification. There can be no reasonable objection to adding to the contract prices for grading, ballasting, etc., a reasonable amount to cover, not so much the seasoning and settling of the new roadbed, as the actual money disbursed in work on this new roadbed during the first 3 or 4 years of operation in order to bring it up to the proper operating condition. A very considerable part of the money spent on "maintenance of track" for the first few years after a new line is built is in reality deferred construction cost.

(*h*) *Apportionment of Values.*—The apportionment of values of locomotives, cars, miscellaneous equipment, shops, and those other parts of the cost which are not susceptible of separation from the operation of the property as a whole, is an interesting and at times a perplexing problem. While the Courts have viewed as equitable the distribution of values between territorial units when made on a track-mileage basis, it is hardly likely that a Court would look with favor on an appraiser appointed by Michigan giving any consideration to values of bridges, track, or buildings in Ohio. Thus far, every State appraiser has concerned himself only with the fixed physical property in his own State, together with his proportionate share of the floating property. The methods that may be considered are track-mileage, car-mileage, locomotive-mileage, and train-mileage.

The method finally used must be such as will give the fairest result for the property under consideration. In some cases one or more of these methods will give a fair value, while in other cases the same system would be most unjust.

(*i*) *Terminals.*—There is no one feature of the entire problem so big with possibilities, and so far from solution, as that of terminal property values and their proper assignment. The property must be considered as an operating unit. Its value must be made up of the values of the parts or elements plus an added value that comes from the operation of the whole. The problem would be simplified if what were sought were the value of a certain railroad, but, as it has been presented up to this time, the problem is: what is the value of that part of this railroad in Michigan? or Wisconsin? or Minnesota? A fairly satisfactory solution of many of the value questions has been obtained, but nothing in the way of a solution of the terminal question. A road owns 300 miles of line in Michigan and 7 miles in Ohio. That 7 miles includes its largest terminal; its principal connections are

there; it has a fine property, and is in the capacity of landlord to several other roads. What part of that terminal value, if any, is assignable to the State of Michigan? Decidedly, it would not be proper to appraise the entire property as a unit and assign to Ohio only the proportion that 7 miles bears to the whole length; it is equally unfair to appraise it as a Michigan property down to the State line, and add nothing to the value by reason of the terminal.

The influence on the value of the property, of the ownership of terminals in such cities as Chicago, New York, Jersey City, Hoboken, Pittsburg, Detroit, St. Louis, Kansas City, and other large centers of population is tremendous, yet a very large part of the railroad mileage entering those cities belongs to roads which have their largest mileage outside the State in which the terminal is located.

There can be no doubt that the influence of a large terminal affects in a measure the value of every mile of line owned by the company; that this influence is greatest on the principal and direct lines, and less as more remote parts of the system are reached. As yet, no plan has been suggested for determining what this value is or for apportioning it.

The final solution in Michigan was to treat terminal properties within the State exactly as other property was treated, and to assume that, if there was any value assignable to Michigan by reason of outside terminals, it would appear as a non-physical value through the earnings.

When all the phases of this question are considered—the enormous land values, the value due to possession of deep-water terminals, the effect on the business of the entire property by reason of the ownership of such properties as those, for instance, in New York City, Jersey City, and Hoboken—it is evident that no appraisal which has yet been made has established any rule of valuation which may be considered proper for terminals.

It is to be hoped that the work now in progress in New Jersey may be so well supported by the State that it will be possible for the appraisal board to make an exhaustive study of this subject and reach definite conclusions as to the real extent, manner of computation, and proper method of distribution of these values.

(*j*) *Development of the Art.*—Is any value assignable to property on account of expenditures by reason of the rapid development of the

art? This question seems not to have been squarely asked or answered in connection with any of the past appraisals.

Every piece of material and every facility purchased by a company is bought with a definite expectation that it will have a certain life, that during that term of life it will add sufficiently to the earnings to provide a fund for its replacement and earn a profit. No matter whether or not such a reserve is created on the books, this is the theory, and, under it, accident may wipe out certain new property, other property will outlive its expectation and maintain the average life of the entire group of facilities.

There are countless cases where this will not hold. The rapid development of large cities has compelled electric lines to extend largely. The demands of the people for more frequent and more rapid service, and more modern and larger equipment, have greatly shortened the term of life of power-plant equipment and cars. The rapid development in the art of electricity, the congestion of traffic in streets of cities, the enormous increase of train movements, and the use elsewhere of newer types of cars, have compelled the abandonment of millions of dollars' worth of property and the investment of other millions in new and improved facilities to provide for the increased movements of traffic and increased safety to the public. These changes are not due to the fact that the original installation was defective, but to the demands of the public for frequent, safe, and speedy service, demands which are perfectly reasonable. The query is: should a corporation which complies with public demands be compelled to lose capital invested in facilities which have not yet paid for themselves; and which, under a continuance of conditions which existed when they were installed, or any that might then have been anticipated, would normally have a useful life of several more years, and which were abandoned, not by reason of being worn out or unfit for service, but purely because facilities of a more modern type were called for?

To answer this affirmatively increases the hazard of investment greatly in the large centers of population. To answer it affirmatively in some cases might amount to confiscation of property. The writer inclines to the view that, as far as appraisal is concerned, the value due to the remaining life of the abandoned facility, where such abandonment was in response to legal requirement, and where no element of corporate necessity due to increased efficiency or economy of the

new facility enters into the computation, should be added to the value of the facility replacing it. Any consideration that is given such claims by an appraiser must be most careful, as the inference to be drawn from the decision of the Court in the Knoxville Water Case (212 U. S., 1) is that such elements of value will receive scant consideration unless most fully supported.

If the policy of the management of any public service company is to keep up with the demands of modern civilization, it would appear that such policy should not be discouraged, and, in computing the value of the property, some provision ought to be devised for covering such values as remain in serviceable property at the time of its abandonment in response to public demand; or else the rates for service should be increased sufficiently to compensate the corporation for losses of this nature on the ground that it constitutes an element of extra hazard.

These and like subjects in connection with the appraisal must be taken up during the period of computation and settled. The computing office organization and methods call for no special comment, except to emphasize the need of experienced men, the use of every possible check on the accuracy of the work, and the prime necessity of keeping all notes in such manner that they can be identified and used to re-establish every step taken in the course of the appraisal.

IV.—The Preparation of the Final Figure.

The final form of the work is, of course, so much a matter of personal judgment that even a suggestion may appear to be useless. The use of such a classification as will conform approximately, if not exactly, with that adopted by the Interstate Commerce Commission is more desirable now than it was 10 years ago, as all the roads in the country are using this classification in their accounts, and the more nearly uniform the work of various State appraisals, the better the results will be.

Non-Physical Values and Methods for Their Determination.

In the published articles treating on the subject of valuation, much stress is laid on the intangible or non-physical elements of value. They have been termed "going concern values," "business values," "good will values," "franchise values," as well as "non-physical" and "intangible" values.

So much of the argument of many writers has been taken up with this phase of the question that it is impracticable to recapitulate the various arguments in support of giving these elements a place in the appraisal.

The writer cannot agree with those who would place any of these elements of value in the physical appraisal.

Value is given to a property, either by reason of the fact that it is an instrument for earning profit, or that it does earn profit or gives promise of profit. The actual investment of capital in a new plant is made with the expectation of earnings. It is not reasonable to attach as physical value, to such a plant, any value in excess of the actual investment. Nor does it appear to be any more reasonable, in the case of an old plant, to assign arbitrary and fictitious values over and above the actual investment remaining in the plant, unless such values are justified and supported by actual earnings in excess of such a rate of interest on the money invested, as it would earn if invested in some non-hazardous security, and—carrying out the clearly-expressed idea of the Courts—such intangible value can only accrue when the rates charged for the service are fair and proper.

The capitalist seeking investment bases his ideas of value on:

(*a*) The market price of stocks and bonds, an estimate of worth based primarily on actual earnings of the property, but affected to some extent by outside conditions; or

(*b*) On the capitalized net income, or actual earnings, of the property; or,

(*c*) In the case of a new property, on an estimate of what the probable earning capacity of the property will be, where the business is more fully developed.

Methods (*a*) and (*b*) ignore cost of construction, or present investment in physical property, and base a value on past performances. Method (*c*) is based purely on hypothetical earnings, but the only real measure of value in this instance is the actual amount of capital that has been invested.

No appraiser would be justified in placing a "going concern" value, in excess of original cost, on a new property, nor would he be justified in placing such a value on a property 3 years old, or 10 years old, unless the net earnings were such as to indicate that the property had a business or commercial value in excess of the physical property value.

It would seem reasonable to say that this difference between the physical value and the value based on earnings represents the "good will," "established business," or "going value," and all the other non-physical elements of value.

To take a specific example: it would be impossible to separate the different elements of intangible value of the Michigan Central Railroad, and say that a certain sum of money represented "good will," another sum "established business," still another sum the "franchise value," and still another sum the "going concern."

The "going concern value" of the Michigan Central Railroad is exactly analogous to the going concern value of the hypothetical water-works cited by Mr. Alvord. Instead of having water pipes connected with buildings along the mains, and considerable sums invested in appliances for using the water, there are manufacturing plants located along the railroad, connected with it by side-tracks built by the industry, and depending on the transportation facilities of the road for their connections with their customers, the very life of the manufacturing plant dependent on its connection with the road. This is "connected good will" of the same kind as described by Mr. Alvord. Yet, to fix a value on it by the method described by him involves going into the realm of conjecture and speculation to a degree that could never be sustained.

Difficulties as great would be encountered in an effort to separate and set up any other elements which go to make up the intangible value, and any figure thus determined would be absolutely incapable of proof.

The Courts say that the value must be the "fair value of the property being used," all the conditions being taken into account (169 U. S., 466).

It can be readily seen that the physical present value is not always —indeed, is not often—the "fair value." The "fair value" may be more, or less, than the present value of the physical property. It would seem to be reasonable to interpret the Court's meaning of the term "fair value" to be the value as a business or commercial property, taking into account the actual investment existing in the property, together with any favorable conditions which would enable it to earn, on rates which were fair and reasonable to the consumer, an income in excess of a usual rate of interest on the actual investment, or any

unfavorable ones which under the same rates would reduce its earnings to less than usual interest. If such an interpretation be allowable, it would appear to be correct practice to use a "fair value" made up of two elements: a physical value, representing the investment, and a non-physical value, representing all the elements which affect that investment to give it favorable or unfavorable financial returns. Is it not, then, proper to conclude that the non-physical or intangible value, composed of all these various elements of value, can only be determined absolutely by a study of the earnings and operating expenses? Is not this clearly what the Court had in mind in the Nebraska Rate Case?

Much of the argument on the subject of "going" values and other kindred elements of value consists of statements of theory and generalities, and may be said to be merely argument to support the theory that there is an intangible element of value. If work of valuation is to be of any real benefit, must it not give a definite result? Must not this result be based on absolute facts?

In securing the present value of any physical property the fixed and certain facts are:

The inventory of property owned.—This is absolute.

The cost of reproduction of the different elements.—This is capable of determination within very close limits.

The depreciation.—This is in a measure a matter of judgment, based on the experience, not only of the engineers making the appraisal, but of the entire scientific world; and, if properly made and properly checked, there should be no very wide divergencies in results.

The items of general expense.—These, based on available statistics, must be estimated. The exact determination of these items will be made comparatively easy as statistics based on the uniform classification of accounts become available.

It is believed that the physical values, when secured along the lines suggested, are definite enough to be accepted as a fair estimate of the amount of capital actually invested in the property, and that, if a sufficiently large force of men experienced in the construction, operation, and financial management of the kind of property under investigation is engaged on the work, the element of uncertainty due to errors of personal judgment can be largely eliminated.

The next question to be determined is whether there is, at the time of the appraisal, any non-physical value, and, if so, to select a method for computing it that will give a result that can be definitely supported as to the particular property under investigation. A study of the income accounts of the property being valued should be made. If the property is not earning a sufficient sum to pay its operating expenses, and taxes, and to set aside a fund to cover depreciation and obsolescence, there is clearly no intangible value of any sort to be added to the physical value. If, however, after all these charges are taken care of, there is a net earning which is large enough to pay 4 or 5% on the physical property and still leave a surplus, is it not perfectly reasonable and proper to hold that this surplus represents earnings on all intangible elements of value?

The contention that all the different elements of non-physical value merge into one intangible value, not capable of separation, will doubtless be objected to by many engineers and corporation managers.

Among the elements adding value to property have been described:

1.—"Going Concern" Value.—Professor Mead defines this as the value due to the fact that a plant has consumers actually utilizing its product, and that it is in actual and successful operation and has its business developed. This value is the worth of the plant in excess of a similar plant without connections, and constitutes an asset in the consideration of its physical value. Mr. Alvord has used the term "connected good will" as applicable to this element of value.

The writer does not concede that "going concern" is a proper element to consider in the physical value, as it does not represent any part of the cost chargeable to capital, and the physical valuation should be confined to the determination of capital invested.

It has already been argued that to the physical property as inventoried should be added proper figures to cover organization, legal expense, administration, engineering, and contingencies. All these items are in the nature of additions on account of the fact that the property is a "going concern." It is maintained that these costs should carry to the present value column as values, for the reason that all these services rendered in connection with the creation of the property remain, unimpaired in value, as long as the property is operated. When, however, a property ceases to be operated, and is abandoned and dismantled, not only do all these elements absolutely dis-

appear, but also all increments of value by reason of the special use of the property are wiped out, and there exist only a lot of partly worn out and partly obsolete machinery and equipment, salable at scrap values, buildings constructed for a purpose which renders them unfit for other use, and land partly salable at going prices and much that will not sell at all.

As long as a gas-works, a water-works, or a railroad is in operation and earning, it is a "going concern," and all increments which attach to its physical property as a whole continue to exist, even if the physical value of the property is greater than a fair value. That fair value can be determined and reached by means of a negative non-physical value.

In view of these things, it would seem to be highly improper to add to physical value anything more for "going concern." In the final report of U. S. Judge R. W. Tayler, Arbitrator in the Cleveland Street Railway matter, in December, 1909, the following language supports the above contention:

"I allow nothing for going value, except in so far as that is the result of the necessary expenditure of money in building the road, acquiring its land, power-houses, and equipment, and putting them into successful operation. The expenditures for these purposes are, and necessarily must be, included in the valuation of the physical property."

2.—Developed Business.—It is perfectly clear that the "fair value" of a property must take into account the established business of the concern. This really is covered by the "going concern values," as defined by Messrs. Mead and Alvord. The only manner in which this can be determined intelligently is by an analysis of income accounts.

3.—Cost of Handling Business.—A railroad with heavy grades, bad curves, poor equipment, or unskilful management is not nearly as valuable a property as one having good line and grades, and far-sighted, economical, and skilful management, and which handles its business at a lower cost per unit.

In such cases the differences in location and management are bound to show in the earnings, adding to the physical value of one property and possibly taking from the value as shown by the physical appraisal in the case of another.

4.—Good Will and Established Organization.—These are valuable assets. It is difficult, indeed, to attach exact weight to these elements

of value, except as they are shown in the intangible value indicated by the earnings. In most cases of public service companies, as is argued elsewhere, it is doubtful if such elements are entitled to any place in a public valuation.

5.—Franchise Values.—These cover various specific items arising out of the ownership of special franchises, or, out of the general rights granted by law to corporations.

All these elements of value have been presented, and have been supported by able arguments. No one has offered a method of separating them. While there is universal recognition of their existence, in the case of many properties, they are supported by nothing visible or tangible. They are practically inseparable, one from another. They are not always present, and the application of any such arbitrary rule as that suggested by Mr. Alvord would make it possible to place values which were purely fictitious. Therefore, it follows that, if they are to be considered at all, they must be treated as parts of one intangible value, and that value must be derived from a study of the income account of the property.

There are other points to be noted as reasons why no such elements of value may attach to the physical property.

Any value of an old and well-established property in excess of a fair return on its physical property (in other words, any intangible value) must be limited and restricted, when used for rate-making purposes, by the value to the consumer of the services rendered. The Courts hold so squarely that the rates charged for services must not be more than the particular service is worth, and that the Company may exact a fair return on property actually being used, that it is not conceivable that any valuation which attempts to attach fictitious elements of value to physical property can be sustained.

This argument is not intended as an attempt to show that intangible values are improper and that where they exist rates should be lowered. It is contended that the determination of rates that will be just and fair to all competing companies involves other consideration than the valuation of either physical or intangible properties, and that when all these rate-making problems are properly solved, there will remain large intangible values on the well-designed plants. It is further contended that the work of valuation should separate the tangible and intangible elements, so that the further work of rate-making or assessment may

not be complicated by improper elements which are included among the items of the physical properties.

In consideration of franchise value, the history of the corporation should be investigated with a view to determine what part the public played in the creation of the property.

The granting of aid bonds, of public lands, and of aid money to railroads, the giving of encouragement to water-works companies by the payment of excessive hydrant rentals, are illustrations of the fostering and development of public service utilities by the public to such an extent as to justify in a large measure the claim that in many cases the allowance of an intangible value is improper as against the public.

A further consideration in the matter of intangible values is the fact that they all partake more or less of the nature of "good will," and the question very properly arises, in the case of a purchase by the public, or of a rate-making valuation: "Should the public be compelled to pay for its own good will?" In the case of such a corporation as a street-railway company in a large city, any value arising from a surplus of earnings is due to the franchise, established business, or going value, or good will of the citizens of that city. This element of value frequently sustains an excessive bond indebtedness. At the expiration of the franchise period the citizens of that city consider a purchase, and are asked to pay, among other things, for their own good will. In view of the attitude of the Federal Courts in the Consolidated Gas Case, and the language of the lower Court in disallowing the item of "good will," which judgment was sustained by the Supreme Court, it is very evident that any attempt to fix arbitrarily a value on such an item in an appraisal is not likely to be supported successfully. The grounds named by the Court are:

Tangible property has a value apart from any franchise or good will value.

The franchise, conferring the privilege to be a corporation, to use public property, to be free from competition, and to enjoy many other privileges, has some value apart from tangible property.

Good will can have no existence as apart from or detached from the franchise conferring the necessary privilege. Such good will (by itself) is not capable of being capitalized and distributed among stockholders.

> Citizens are entitled to have gas (or water) because they pay for it, exactly as they are entitled to have clean streets (and, in the same way, police protection or fire protection), because they pay taxes among other things for that.

The Court, therefore, finds that there is no good will value in connection with the gas business in the City of New York, although it is said, elsewhere in the finding, that it is the best, most favorably located, and most prosperous business of its kind in the country.

Judge Tayler, in the Cleveland Railway arbitration, says:

"I allow nothing for good will. A street railway company which has a monopoly, and especially if it has a franchise value remaining, can have no good will value."

Judge Lurton, in the Omaha Water-Works Case, says:

"That kind of good will, as suggested in Willcox *vs.* Consolidated Gas Co., is of little or no commercial value when the business is, as here, a natural monopoly with which he must deal, whether he will or no."

In connection with a consideration of franchise values, the following points are raised by the Federal Court in the Consolidated Gas Cases (157 Fed., 872-879):

"Should a corporation have a right to demand an income return, separable from any return upon its tangible property, from its right to place gas mains in the public streets and maintain them for its private profit, a right which it did not buy from city or state or pay therefor any legal valuable consideration? The Court thinks not, because 'Return can be expected only from investment, and he that invests must part with something in the act of investing.' Does any company invest its franchise in its business? It does not part with its franchise in the same way it parted with money or money's worth in acquiring or creating mains or plants. The investment of property was made, not in the franchise, but under the franchise, and on the faith thereof. The franchise is but a part of the power or sovereignty, allotted to a private person for the benefit of all, and only incidentally given for private emoluments.

"What is the value of a franchise to perform a certain service, under which no money is invested and no service yet performed? What is it worth apart from performance under it?

"Unless it can be seen to possess inherent value entirely apart from the earning capacity of the subsequent investment or from the actual earnings resulting from such investment, the value asserted or claimed is but a duplication of that derived from the use of the tangible property when so invested.

"The concepts of the nature and value of franchises are seen dimly and confusedly because of the failure to distinguish between productive and non-productive property. Land, money, chattels may by industry and intelligence be made productive without a franchise; but no excellence in these desirable qualities can ultimately render a franchise productive without the use of money, chattels, and land in connection therewith, and when the juncture is made the earning capacity of the real and personal property, plus the franchise and plus intelligence and industry, is really no greater than it would be without the franchise, for the franchise has added no producing power to the realty or personalty; it has but authorized their employment in a particular way and protected the owners while so employing them."

The Court emphasized the fact that the particular way in which they are used is in performing a function of the State—in doing a service for the public which the public might do equally well for itself, in the following language:

"I can imagine no more than three ways in which the value of a franchise can be stated. It is valuable: (1) because it authorizes the gainful use of private property in a particular manner; (2) because once obtained it is often difficult or impossible to get another like it; (3) because it may be used to injure or hinder another enterprise, although itself conferring or securing nothing of value.

"The third method of statement has been accurately, though colloquially, described as a 'nuisance value,' and is so obviously illegitimate as to require no discussion. The second method of statement, when carefully considered, asserts that because the sovereign has deemed it advisable to entrust a public work to one citizen or a body of citizens such quasi monopolistic grant confers the right to charge for the service more than would be just or lawful were the occupation open to all. Nor does it change the truth of the last statement that the difficulty of procuring franchises produces, and long has produced, a traffic in them. On every private sale of franchise property, the price paid is so much money lost to the public by official incompetence or worse, and such sale can confer on the vendee no right to compel the consumer to repay him a price that should have been paid to the State. For these reasons, I believe that on principle a franchise should be held to have no value except that arising from its use as a shield to protect those investing their property on the faith thereof, and that, it renders fruitful, it possesses no more economic value for the investor than does an actual shield possess fighting value, apart from the soldier who bears it."

It will not do to leave this decision without calling attention to the fact that the foregoing quotations are but argument advanced by the Court, and that he found a franchise value, following the reasoning

of the Supreme Court in cases cited heretofore, and other cases, and upon the doctrine that:

"Private citizens may acquire vested property rights through a series of even erroneous decisions; rights so firmly vested that it becomes unconstitutional for the court which persisted in error suddenly to rectify its mistakes to the detriment of those who had securely rested upon the decisions sought to be invalidated."

After citing numerous cases, and considering methods of valuing franchises, the Court says:

"I think it obvious, as I have endeavored heretofore to point out, that either for the purpose of condemnation or regulation the value of a franchise depends wholly upon what is earned under it and I believe the best way of finding out how much a franchise, separately considered, is worth, is to ascertain what those persons desirous of continuing operation under it consider it to be worth. In a corporation whose stock is freely bought and sold, such value is measured by the success attending the sale of stock based entirely upon capitalization of the franchise; yet the value of stock issued only in consideration of the franchise is obviously dependent on earnings after the stock based on tangible property has received a satisfactory dividend * * * yet it will always be true that, unless the whole net return, compared with the value of tangibles, is above a satisfactory return on tangible investment alone, the addition of stock issued for franchise will be regarded as 'water,' and detract from the value of the entire issue, and I think this conclusive proof that value on a franchise depends wholly on what actual investment can earn."

In this particular instance stock to the amount of $7 781 000 had been issued in 1884 and divided among stockholders without any consideration, which stock represented the company's own valuation of its franchise at that date. The Court, in fixing a value, held that it would be proper to increase it proportionately to the increase in tangible property; this he did, fixing the franchise value at more than $12 000 000. The Supreme Court of the United States, in disposing of this, says (212 U. S., 47):

"But although the state ought for these reasons [applicable to this case—not general], to be bound to recognize the value agreed upon in 1884 as part of the property upon which a reasonable return can be demanded, we do not think an increase in that valuation ought to be allowed upon the theory suggested by the Court below. Because the amount of gas supplied has increased to the extent stated, and the other and tangible property of the corporations has increased so largely in value, is not, as it seems to us, any reason for attributing a like pro-

portional increase in the value of the franchises. Real estate may have increased in value very largely, as also the personal property, without any necessary increase in the value of the franchises. Its past value was founded upon the opportunity of obtaining these enormous and excessive returns upon the property of the company, without legislative interference with the price for the supply of gas, but that immunity for the future was, of course, uncertain, and the moment it ceased and the legislature reduced the earnings to a reasonable sum, the great value of the franchises would be at once and unfavorably affected, but how much so it is not possible for us to see. The value would most certainly not increase."

The Court did not concur in the increase of the franchise value, and, in dismissing this subject, says:

"What has been said herein regarding the value of the franchises in this case has been necessarily founded upon its own peculiar facts, and the decision can form no precedent in regard to the valuation of franchises generally where the facts are not similar to those in the case before us."

It appears, then, from this, the latest case, that:

1.—The view of the lower Court that a franchise or intangible value is not separable, and that if there be a value it must be determined from the earnings, is concurred in by the Supreme Court.

2.—That the arbitrary increase of franchise value, by the lower Court, proportional to the normal increase of the physical property, is not concurred in.

3.—Inferentially, it appears that the acquiescence of the State in the franchise value of 1884 is the main reason for permitting that value to stand, and it would seem to follow, from the reasoning of the Court, that it is very questionable whether any franchise or intangible value based on excessive rates should be allowed to stand.

Another view of franchise values, as stated by George H. Benzenberg, Past-President, Am. Soc. C. E., in discussing water-works franchises, is as follows:

"Some contend that a franchise is simply and purely a privilege given by the municipality to a water company to utilize the streets for the purpose of laying a system of pipes through which it may distribute and deliver water. It is not a license to do business, but a privilege to use public streets, alleys, and grounds. * * * If that interpretation is the proper one, the value of the franchise, if the property is to be purchased by a municipality, is comparatively nothing. If the property is to be purchased by another company, it represents

all of the great value that such franchise possesses to the original holder, together with all the privilege it confers; but in the event it is purchased by the city, it is dispossessed of that certain element of value, and I think for that reason it is stipulated in many of the ordinances that no value shall be placed on the franchise by appraisers."

In the paragraph just quoted, it is evident that the term "franchise" is used in a restricted sense, and refers to the ordinance or contract from a municipal corporation granting the right to operate on specific terms, rather than the broad use of the word as indicating all rights derived from general laws or special contracts or grants. The point, however, is applicable to the case of any corporation occupying public ground.

It is believed that enough argument has been adduced to show that any attempt to give separate value to the different elements that enter into the intangible value of a property is a very risky proceeding on the part of appraisers, and to support further the contention that, as a business proposition, the value of any property depends on its earnings; that the franchise simply protects the owners of the property in their enjoyment of those earnings; that the value of the franchise merges in the "fair value" of the property, and that the franchise can have no special value of itself unless the earnings of the property are in excess of a usual and fair rate on the actual investment. In case there are surplus earnings, they measure and determine not only the value of the franchise, but also the value of all other non-physical elements. If this be true, any readjustment of rates, any restriction of operations, or other form of legislative control which would unfavorably and violently affect earnings, is bound to hold down franchise or non-physical values; as it would not seem possible to read into the various decisions any intention on the part of the Court to base the right to demand fair return on anything but the "fair value of the property being used."

The writer, therefore, reaches the following conclusions regarding non-physical values:

1.—That all the different non-physical elements of value are inseparable.

2.—That in the case of very many properties, no non-physical value can attach, and in many cases this value will be a negative or subtractive quantity.

3.—That in the case of properties located so as to secure either a monopoly of business in a congested territory, or in which the construc-

tion, location, strategic position, or economic excellence of design, is such that, on a schedule of rates which is fair and reasonable for competitors less advantageously situated, an earning is secured which is in excess of usual returns, a non-physical value of considerable magnitude may very properly be assigned.

4.—That, for the computation of non-physical values, the income account of the property under consideration affords the only legitimate basis, but even then consideration must be given to duration of franchise, reasonableness of rates, and other modifying conditions, and also, possibly, the purpose for which the appraisal is made may determine whether or not a non-physical value may be used. The language of the Court in the Knoxville and Omaha cases apparently leaves this a very open question.

This brings us substantially to the conclusion reached by Professor Adams in 1900, and a careful study of the method laid down by him shows nothing that cannot be accepted as fair and reasonable. His plan should be extended so as to cover subtractive values or the case of properties showing a deficit.

This method has the merit of being based on the actual earnings and expenses of the company under investigation and on the value of the physical property as already computed. It does not introduce a mass of purely supposititious figures, nor depend on hypothesis. The proposition is simply this: If a property earns only its operating expenses, including therein proper depreciation reserves, taxes, and such a percentage on its actual invested capital as could be earned by that capital if invested in good non-taxable bonds or other like security, it is worth no more than its physical property is worth. If it earns more than that, it is due to the franchise, going concern, or other intangible elements of value, and, to determine that value, capitalize the surplus.

It takes several years for a property to reach its normal earning capacity after construction is completed, and, in the investigation of a property of comparatively recent construction, where the gross and net earnings show a steady annual increase, the application of a negative or subtractive value should be made with great caution; but where the earnings have been fairly uniform and stationary for a period of years, and the property does not earn a sufficient sum to care for depreciation and annuity, it is clear that the value as an earning investment is

less than the determined physical value, and that the physical valuation should be reduced by some amount to arrive at the "fair value."

The Courts hold that public service corporations are entitled to earn:

(*a*) Operating expenses,
(*b*) Expenses of maintenance and running repair,
(*c*) Taxes,
(*d*) A sinking fund from earnings to cover depreciation and obsolescence, and
(*e*) A reasonable profit on the fair value of the property.

An investigation of non-physical values should then include an analysis of operating expenses, to determine that additions and betterments to property are not included therein.

The general practice of corporations in the past has been to ignore any reserve to cover depreciation and obsolescence. If, at the beginning of operations of any property, such a sum should be annually set aside out of earnings as should, when invested as a sinking fund, maintain the integrity of the investment, then this amortization fund at any period, plus the depreciated value of the physical property, should equal the amount of the total capital actually invested in the property. In most cases this has not been done, and the Supreme Court in the Knoxville Water Case holds that, by reason of the failure to create such a fund, whether due to carelessness, excessive dividends, or other cause, the company must lose the amount of capital represented by the depreciation that has taken place. In making a computation of intangible values, it is certainly proper to consider the income account as averaged over a period of years, to avoid violent fluctuations of gross or net earnings, and a depreciation reserve should be determined for such years, as it cannot be claimed that, unless such an amortization fund is earned, in addition to other operating expenses and taxes, there is any non-physical value.

Professor Adams covered the depreciation in the Michigan work in the 4% annuity which was deducted before non-physical values were computed. The writer is inclined to go a step farther than Professor Adams, and hold that, before any intangible values can be attached to the property, it should earn not only all operating expenses, taxes, and reserve for depreciation, but also interest on the actual investment equivalent to the return that would be had were the money invested

in a non-taxable bond, say 4%, and that any earnings in excess of such a sum might be termed properly "earnings on franchise," or intangible values.

On this basis, then, a rule would be formulated, being that of Professor Adams, with some modifications:

1.—Deduct from gross earnings from operation the aggregate of operating expenses, including in operating expenses an anual sinking fund to amortize the depreciation and obsolescence, and the remainder may be termed "income from operation."

2.—To this income from operation add income from investment, giving "total income," which represents the amount at the disposal of the corporation for the support of its capital and for the determination of its annual surplus.

3.—From "total income," deduct taxes, rents paid for lease of operated property (provided such property is not included in the appraisal), and improvements chargeable to income. The remainder represents the income after all charges against operation of property, and maintenance of the integrity of the capital investment have been cared for.

4.—From this remainder (*3*) deduct such a percentage of the value of the physical property (representing invested capital) as would equal the income of that capital if invested in government or other non-taxable bonds. The remainder would represent surplus, which, capitalized at a proper rate, would equal the value of intangible or non-physical properties, which is to be added to the appraised value of the "physical property."

5.—If, instead of a surplus, a deficit occurs, a careful study of all the conditions surrounding the operations of the property should be made, and, if there be no reasonable expectation of increase of earnings, or other modifying conditions, a proper figure, based on the average deficit, should be determined, and, as a negative intangible value, deducted from the value of the physical property.

6.—In the determination of rates, to be used in computing income and for capitalizing surplus or deficit, the greatest of care must be exercised to adopt such figures as will be proper and absolutely just.

Conclusion.

The subject of valuation is so appallingly great that, notwithstanding the length this paper has reached, many points have not been covered.

No discussion of the method of valuation by capitalization of net earnings, which is practically that adopted by Professor Adams in his commercial valuation, has been attempted; nor has any attempt been made to describe the stock and bond method. Neither method is adaptable to the requirements of any public appraisal.

The so-called cash investment in property, or the actual cost of construction through the entire history of the property, cannot be sustained by any process of argument as a proper method of valuation, nor can the method of computing the cost of construction of an adequate modern property assumed to replace the existing property. The scope of a valuation must be limited to the property as it exists on the date of the appraisal, and it would be equally fallacious to include non-existent and long-perished facilities, or to assume a hypothetical and never-existing property.

There are many intricate problems in connection with a valuation for rate-making or taxation which really belong to these undertakings, not to valuation. They are usually brought into the discussion of valuation, but have been here excluded. Among these are the separation of interstate from intra-state business, and others, of great interest, it is true, but foreign to the subject of valuation.

The question of the fair return on money invested is not referred to, for the reason that it has no direct bearing on valuation, and for the further reason that it has been quite exhaustively discussed in the papers listed in the Appendix. The writer desires to make clear the fact that he is not advocating low rates *per se*. The rate must be determined to meet the special requirements of each investigation. The Supreme Court of Maine says (97 Maine):

"The reasonableness of the rate may for a time be affected by the degree of hazard to which the original enterprise was naturally subjected. That is such hazard only as may have been justly contemplated by those who made the original investment, and not unforeseen and emergent risks, and such allowances may be made as is demanded by ample and fair public policy."

While the Supreme Court of the United States, in Willcox *vs.* Consolidated Gas (212 U. S., 12), fixed a rate of 5½% as reasonable in that instance, they said:

"No particular rate of compensation must in all cases be regarded as sufficient for capital invested in business enterprises. Such compensation must depend greatly on circumstances and locality. Among

other things the amount of risk in the business is an important factor, as well as the locality where the business is conducted and the rate expected and usually realized there upon investments of a somewhat similar nature with regard to the risk attending them. There may be other matters which in some cases might also be properly taken into account in determining the rate which an investor might properly expect or hope to receive and which he would be entitled to without legislative interference. The less risk, the less right to any unusual return upon the investments."

In view of these dicta, it is needless to argue whether a rate of 6% or 10%, or 15%, or more, be reasonable.

The writer has herein endeavored to narrate the story of the Michigan appraisal in some detail, to review briefly subsequent similar work, to present the main points in the legal decisions bearing on appraisal practice, and to present his own views as to proper and legitimate methods of valuation in the light of judicial opinions. He has attempted to do this in the spirit of absolute fairness, without permitting either early years of training in corporation service, or more recent investigations for State and city, to bias the presentation of truths.

The subject is one which has not attracted the average citizen sufficiently to compel him to give it deep study. Those who are familiar with it all too frequently have views biased by interest, and it is hardly conceivable that any final conclusion will be reached until each and all of the main issues are determined by the Courts. When thus determined, it will be done with wisdom and with justice. It is impossible to study the cases referred to without being impressed with the absolute fairness of this great tribunal. Quotations from decisions have been included at considerable length in order to obviate the criticism that the references do not convey the exact meaning of the Courts.

The writer acknowledges the valuable suggestions, criticisms, and information furnished him by Professors Henry C. Adams, Mortimer E. Cooley and W. D. Pence; Mr. Henry L. Gray, Engineer of the Railroad Commission, Washington; Mr. D. F. Jurgensen, Engineer, Railroad and Warehouse Commission, Minnesota; Mr. Bion J. Arnold, and others who have made possible the presentation of data regarding State and other appraisals.

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DISCUSSION

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FRED LAVIS, M. AM. SOC. C. E.—The author states that his paper is confined to "a discussion of the methods which should be used in arriving at a correct figure of cost of reproduction and depreciation," and that "it does not take up questions involving the propriety of those figures when reached." In so far as this is concerned, it is probably the most complete compilation of the available information on this phase of the subject which has yet appeared in print. The author refuses to recognize that the consideration of the so-called intangible values has any place in a physical valuation. As, however, there exists such a widespread feeling, especially among those interested in railroads, that physical valuations, for any purpose whatever, are absolutely useless, because these intangible values are not or cannot be included, it does not seem out of place to refer to this phase of the subject at this time, and more especially in view of the fact that many persons, the prominence of whose position entitles them to consideration, have taken this point of view very recently, and their remarks have received considerable publicity. Not more than two weeks ago, Judge Lovett, the head of the Harriman System, expressed the opinion that the theory of valuing railroad property by trying to determine the cost of reproduction was utterly impractical. It seems important, therefore, that we, as engineers, interested in having the question properly understood, should be careful, in referring to valuation, to make it plain that other features besides the value of the physical property are to receive due consideration. The speaker, therefore, proposes to examine some of the arguments advanced by the opponents of valuation to see if the objections most generally brought forward are insuperable.

Some critics of valuation go so far as to say that engineers cannot make a close valuation of even the purely physical property. For instance, Mr. W. H. Williams, Vice-President of the Delaware and Hudson Company, in a paper on this subject,* states that:

"No engineer in estimating on the several important items of construction work for the year will come within 10 per cent. of the total aggregate cost. Many of the more important items are frequently underestimated 25 to 50 per cent."

He cites, as an especially good illustration, the Panama Canal, the original estimate of the cost of which was $140 000 000, though the present estimate is $300 000 000. Almost every one who has kept in touch with that subject knows why the Panama Canal has cost more than the original estimates, and that the greater cost is no reflection on the judgment of the engineers who made such estimates. One

* *Electric Railway Journal*, January 8th, 1910, p. 76.

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cannot always foresee what changes in plans may be made before construction is completed, and would hardly expect the estimates of the cost of a railroad to be adequate if they were made for a single-track road and a double-track was built. In any event, there is a vast difference in estimating the cost of an engineering work already completed and one which has yet to be started, the difference being largely in favor of a closer estimate of the completed work.

Limitations are often placed on engineers, in connection with work they do, which are afterward forgotten. The speaker was asked not long ago to prepare a report in connection with the valuation of a large railroad property. The time within which the results were required was very limited, and the methods used in the valuation necessarily had to be a combination of the inventory method and reliance, in a great many matters, on the judgment of those making the appraisal. Undoubtedly the result obtained was entirely adequate for the purpose for which it was required, but would hardly stand if an attempt were made to use it as a basis for an argument before a Court of law or a public service commission, though it would not be beyond the range of the experience of many engineers to have a matter of this kind brought forward some time in the future as an absolute statement of fact, with no reference to the way in which the work was done.

It is inevitable, of course, that engineers will differ in their opinions as to some details of methods of making an inventory of the property of a railroad or other public service corporation, and also as to exactly what unit prices should be applied, but in general it is safe to say that any engineer of proper experience and training can make a satisfactory appraisal of the value of the physical property of a railroad, and that if two or more such competent fair-minded engineers, unhampered by any consideration of the purpose for which it is to be made, should make such an appraisal, the variation in the result would be so small as to be negligible. The speaker, however, does not entirely agree with the author, that the purpose for which the appraisal is to be used should be entirely ignored by those who are making it. There can be little doubt as to the propriety of using a properly made physical valuation as a basis for taxation, or as information for the owners, although there may be some as to the methods whereby the so-called intangible values are to be determined in these cases, or even whether they should be considered at all. The greatest difference of opinion arises when an attempt is made to regulate the issue of stocks and bonds, or to fix the rates which should be charged for transportation, on the basis of a physical valuation.

Arguments for and against rate regulation revolve in a circle, and, apparently, there is no starting point which will satisfy every one. The Courts have ruled that the railroads are entitled to such rates as will enable them to earn a fair return on the value of their property;

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the railroads claim that the only way to determine this value is on the basis of the earning capacity; that is, one side claims that the rates must be based on the value and the other that the value should be based on the rates. It is evident, however, by this time, that the railroads must submit to regulation, therefore a way must be found to break into the circle, and it would seem to be incumbent on them to direct their energies along lines which will tend to make such regulation fair and just rather than to oppose it entirely. There is little claim that unduly large dividends are paid, but there is a feeling in the mind of the public that the railroads are over-capitalized. Is it not possible, therefore, to break into the circle at this point, and decide, by means of a proper valuation, as to the fairness or otherwise of the capitalization? The objection to this, on the part of the railroads, is that the value of the purely physical elements is by no means the whole value of their property, but that something should be added for the so-called intangible values.

To emphasize the difficulties of appraising the intangible values in any way which will permit the application of such value to the determination of rates for transportation, the opponents of physical valuation cite what is now the familiar instance of two mythical roads between the same termini, the first with good alignment and easy grades following a valley, and the second forced into the mountains, having not only heavier grades and more curvature, with consequently a higher cost of operation, but also more expensive construction. The value of the purely physical features of the former, of course, would be much less than those of the latter, but its actual value as a property would be greater. How then should the rates on the two roads be fixed? The fallacy of using this example as an argument against physical valuation as a basis for rate-making is in assuming that there would be two railroads built under such circumstances, with no other features than the two termini and the line between.

One has only to call to mind such examples of competing lines as those of the Denver and Rio Grande between Denver and Salt Lake, the Union Pacific between Cheyenne and Ogden, the Lackawanna and New York Central between New York and Buffalo, or many others, to realize that there are, on all roads of this nature, many other factors than the actual cost of operating through trains between the termini, which determine the through rates.

One would hardly suppose that at this late date any one believes that it is proposed to use only the value of the purely physical property of railroads as a basis for rate regulation, yet the *New York Sun*, a paper of national prominence and usually most ably edited, devoted a column of its editorial page* to a discussion intended to show that rate regulation, based on physical valuation alone, was an impossibility.

* December 4th, 1910.

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In addition to citing the example given above, the following is put forward as the *reductio ad absurdum* of the argument for rate regulation based on physical valuation. It is said:

"Suppose there are two bridges over the Ohio, the *cost of the construction of each being the same,* one between Cincinnati and Newport and the other twenty miles below where there is nothing but a village on either shore. * * * On what basis would the proponents of physical valuation, as the determining value in rate making, adjust a toll charge on these respective bridges?"

The example is far-fetched, and in no way applicable to the question of the adjustment of rates on railroads, but inasmuch as it is seriously put forward from a responsible source, it seems worth while to consider it.

Assuming, as apparently the propounder does, that the proposition is uncomplicated by any questions of franchises, public rights in the land on which the bridge and its approaches are built, etc., then there is no question but that the owners of either bridge have a perfect right to charge what toll they please. On the other hand, suppose the permission of the War Department, or some other governing body, had to be obtained in order to build piers in the river, or even to build the bridge at all; the argument used in asking for this permission is that the bridge is needed as a public convenience; or it is desired to occupy certain streets for the approaches, again is used the argument of public convenience, and so on. These privileges are granted on the tacit understanding, at least, that the public convenience is to be served, and the Courts rule that, in such cases, in consideration of the equity which the public has in the property by reason of the rights granted, a fair return on the value of the property, but no more, should be the basis for establishing the rates of toll. Would the *Sun* claim that the value of the rights and franchises given by the public in such a case, be included in the value of these bridges, and that a higher total income should be derived from one bridge than the other because the value of the streets on which the approaches had been built is greater in one case than the other; or that a greater income should be derived in one case than another because the cities furnish more people than the villages? Is there any particular reason, except for the slightly larger depreciation and cost of maintenance, and, bearing in mind the fact that both bridges cost the same, why, if there is ten times as much traffic on one bridge as on the other, the toll should not be proportioned accordingly, to provide the same income on each?

If the *Sun* had imagined a bridge built by private individuals, with their own money, between two villages, the inhabitants of which, at the time the bridge was built, having been willing to grant almost any franchises or privileges in order to get the bridge, the villages in course of time growing to large cities, and the old bridge having been

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replaced by a heavier modern structure, the example might have been more nearly comparable to the railroad situation. In this case, the original toll, of say 10 cents a head, may have, in the early days, only barely returned a meager rate of interest on the investment, or even for some years resulted in a deficit. Would the *Sun* uphold the owners of the bridge if, since the villages have grown to cities, they still insisted on collecting the original toll, if it could be shown that a new bridge could be built and would be a paying investment with a toll of, say, 2 cents, except for the fact that the original bridge was built in the only location where it was practical to build a bridge at all? Or is it reasonable to say that the foresight and energy of the owners of the bridge, even though it may have been one of the principal factors in enabling the villages to grow into cities, entitle them to capitalize their enterprise on the basis of a 10-cent toll? It cannot be denied that the energy and foresight of the original builders should be recognized in fixing the rate of toll, but there is a limit to the value of this, and it is because of the feeling on the part of the general public that the capitalization of similar intangible values on the part of the railroads and other public service corporations is too large, which, whether true or not, has caused the present agitation against them. If the capitalization is reasonable, there must be some way to demonstrate the fact, and it seems as if a properly made physical valuation, with due allowance for the intangible values, is at least a step in the right direction.

The *Sun* states in its editorial that:

"The scheme of physical valuation, as a basis for rate making, is flatly rejected as unworkable by practically all the ablest railway authorities of the country, and that the only true measure of value is the earning capacity."

To quote only one, namely: Dr. Emory R. Johnson, who is generally regarded as an authority and not by any means predisposed in favor of the public as against the railroads, it is found that he states in his "American Railway Transportation" that:

"The earning capacity of the railroad cannot be equitably or logically made the sole criterion of value, because the rates, and hence the earnings, should depend to some extent, at least, upon the amount of capital justly entitled to profit."

It would seem to be self-evident that the earnings alone, either gross or net, are not necessarily an indication of the value of the road. Gross earnings are not, because, if a minimum proportion of them is used for maintenance and betterment, the value of the property will steadily decrease; whereas, if the opposite policy be followed, it will increase. On the same principle, the net earnings offer no criterion as to the manner in which the property has been kept up, and alone are, therefore, no measure of its true value.

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As an example of the arguments used by some of the opponents of physical valuation, the following quotations are made from an article by Mr. Henry Fink, Chairman of the Board of the Norfolk and Western Railway.* Referring to the fluctuation in the costs of construction, he says:

"As the cost of materials and labor fluctuates * * * it follows that what may be a fair valuation of a railroad one year may not be so one or two years later. Hence, it would be necessary to make new valuations from time to time."

Further, in the same article, referring to a valuation based on the market value of bonds and stocks, he says:

"Unlike the physical valuation, this method has a rational basis. * * * It is true that prices of stock fluctuate—at times violently—but this difficulty can be overcome in a measure by using the average prices for long periods."

It is strange that it did not occur to so able a man as Mr. Fink that the value of the physical property might also be based on average prices for long periods; the cost of railroad construction and equipment as a whole does not fluctuate nearly so violently as the stock market.

The report on "The Basis of Unit Prices,"† by W. D. Pence, M. Am. Soc. C. E., the Engineer of the Wisconsin Railroad Commission, in connection with the Appleton Water-works case, is an excellent example of a fair and impartial study of this phase of the subject, and the conclusion of the Commission in this matter can only be regarded as reasonable by any one who is disposed to be at all fair-minded. It says:

"If the standard by which the reasonableness of charges is to be determined should fluctuate with the market prices of material, labor and land, no schedule of rates could be established for any length of time, for, under the circumstances, a rate that would be reasonable to-day might be very unreasonable to-morrow. The principles of the law applicable to the subject certainly involve no such absurd consequences."

Another instance of an argument based on technicalities is found in the *Railway Age Gazette*.‡ In an editorial on Valuation and Rate Regulation, it is said:

"It has been supposed in the past that rate-making is an exercise of judgment. It seems to be assumed by many that after a valuation has been made it will be merely an exercise in mathematics. Suppose the value of a railway for state purposes is $50 000 000. Then, on this theory, all that will have to be done will be to multiply this amount by 6 per cent.—or whatever may be regarded as a fair return—and so adjust the rates as to enable the road to earn, say, $3 000 000 a year,"

* *Railroad Age Gazette*, July 24th, 1908, p. 587.

† *Engineering News*, June 16th, 1910, p. 697.

‡ March 4th, 1910.

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but, the writer goes on to ask, "how are the specific rates to be fixed? A great majority of those who advocate valuation say that they should be based on the cost of the service. The proper method, then, would be to ascertain the exact cost of hauling each commodity and then base rates on these ascertained costs, making them just high enough to allow the road a fair return."

Then the article goes on to point out the difficulties of doing this, which of course we all know, and finally concludes that: "The theory of basing rates absolutely on the cost of service is unjust and impracticable." In the present state of the art this is probably true, but why is it necessary to change the present theory of rate-making because the rates are to be lowered or raised? If, for instance, it is shown that it is necessary to reduce the rates sufficiently so that the net earnings will be reduced, say, approximately 10%, is it beyond the capacity of the traffic officials of a railroad to adjust their rates accordingly?

In an editorial in another part of this same issue the *Gazette* advocates the raising of rates to meet higher prices of supplies and higher wages; it is surely as feasible to lower rates as it is to raise them, and, even though it were necessary to base rates on the cost of service, it does not seem as if that would be entirely impractical, inasmuch as it is the whole argument advanced for raising the commutation rates on the railroads entering New York City. Will the *Gazette* say that the arguments put forward by these railroads are all wrong? Mr. Fink, in the article* already referred to, states:

"It cannot be said that * * * railroads make tariffs; they can only adjust them to varying conditions."

* * * * * * * * *

"Adjusting freight rates is practical work of men who have special training for it and large experience. They may not all be able to explain underlying principles, such as the value of service, but they have used this principle for years, and apply it intuitively in every case which comes before them."

Surely this body of men is equal to whatever adjustment may be necessary. Rates will probably never be arranged to suit every individual shipper; but if the people, as a whole, believe that the railroads are fairly capitalized on a reasonable basis of value, and the rates, in the aggregate, are adjusted so that unduly high profits are not made, individual complaints of injustice may easily be taken care of.

The most important considerations affecting the regulation of railroad rates arise in attempting to fix the amount which shall be considered a fair return on the investment. If a certain rate of interest is fixed as the maximum which may be earned, all incentive toward improvement or progress is removed. The effect of this would be, of course, to retard all development. Once a railroad was earnings its

* *Railroad Age Gazette*, July 31st, 1908, p. 627.

Mr. Lavis.

legal rate of interest, there would be no necessity of cutting down grades, building larger locomotives to handle larger trains, investigating the economics of operation and location, in order to introduce the thousand and one economies which are being developed day by day, or for our railroad presidents to lie awake nights thinking how they are to save that million dollars a day for the benefit of the always ungrateful shipper. This objection against rate regulation, and incidentally against physical valuation, can undoubtedly be overcome. One proposal which has been made is somewhat along the lines on which it is proposed to finance the New York Subways, the profits to be divided between the railroads and the State, after a certain rate of interest had been earned. There is nothing novel about this, as several railroad charters have been granted with a provision that all earnings, over an amount necessary to provide a certain rate of interest, should be paid to the State. Another suggestion* is that the reasonable rate of return be fixed as a percentage of the gross income, irrespective of the amount of capital required to produce it. There are probably other ways in which this might be worked out and adjusted, and this phase of the subject surely does not present any insuperable objections.

That the railroads have little to fear, in regard to capitalization, from a properly made valuation, is shown by the results in the State of Washington, where the valuation was undertaken solely for the purpose of fixing rates, the result being a determination of the market value of the three principal railroads of the State—the Northern Pacific, Great Northern, and Oregon Railroad and Navigation Company—at an amount considerably in excess of their capitalization.† It is true that rates were lowered in this case on some commodities, but it does not necessarily follow that every change of rates on the basis of valuation must be toward a lower scale. Railroad rates are low and have stayed low while the cost of everything else has been raised, and yet, while this fact is well known to the general public, they still believe that, in some way or another, the railroads are getting or have been getting more than their proper share of profits. Evidently there is something wrong somewhere, and it is not going to be set right by calling the public fools and ridiculing their presumption for meddling in any way with railroad affairs. Mr. F. W. Whitridge, the Receiver of the Third Avenue Railroad, of New York, while stating‡ that he had only just discovered that there was such a thing as valuation, at the same time held up the whole scheme to ridicule, though he admitted that:

"The people of this country have, I think wisely, made up their minds, in consequence of great corporate abuses, that public service corporations should be subject to regulation, etc."

* *Engineering-Contracting*, May 25th, 1910, p. 468.

† *Railway Age Gazette*, March 4th, 1910, p. 437.

‡ *Electric Railway Journal*, January 15th, 1910, p. 110.

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He nevertheless ridicules the efforts of the authorities, particularly their endeavors in the matter of valuation, with its "irreverence for facts." They seem, he says, "to be singing the song of the Banderlog who dreamed of

"'Something noble, grand, and good
Won by simply wishing we could.'"

Valuation, however, has gone far beyond the point where it can be considered a visionary scheme, or can be held up to ridicule; and it has been worked out far enough to show, at least, that there is a rational basis, on which a determination of values can be made, which will do justice to both sides; furthermore, the Supreme Court of the United States has not only ruled that valuation must necessarily be precedent to rate regulation, but has gone so far as to specify at least some of the elements which must be taken into account, and it may be worth while noting that, in spite of the author's criticisms of the Washington State Valuation, it is the only one, thus far, in which an attempt has been made to comply with the rules laid down by this Court. The results in Washington, however, indicate clearly the need of regulation of the railroads, as a whole, and not varied regulation by individual States of the parts of systems within the borders of each.

Arguments on either side can be prolonged indefinitely, and many good reasons for and against physical valuation are advanced from time to time, just as they may be on any proposition. Some of the principal objections have been referred to here in an endeavor to show that they are not insuperable; the point which concerns us now is that to-day we are confronted with a fact and not a theory, and that fact is that the railroads are going to be regulated, and that their proper development is held back and general business is hampered by the feeling of uncertainty as to the outcome. Physical valuation is not a panacea for all evils, but a properly made valuation of the physical elements, with a due allowance for the intangible values, based possibly on some such method as that developed by the Washington State Commission or by Professor Adams in Michigan, is surely as good a way of breaking into the circle of argument as any that has been proposed thus far.

The equipment of freight trains with air brakes and safety couplers was practically forced on the railroads by the pressure of public opinion led by laymen, yet one will hardly find a railroad man now who will not admit that this is good practice, not only from the standpoint of safe operation, but from that of economy as well. The early attitude of the railroads in this matter is already being quoted by the advocates of valuation, and inasmuch as we have to admit, as we surely do, that a start is going to be made somewhere along the line of obtaining some more definite information in regard to the true

relation of the value, capital, and profits, of railroad properties, than the mere statement by the railroads themselves that they are all that is good and fair, would it not be wise on their part to do all they can to have the start made properly rather than oppose it? Some of the most prominent and progressive railroad men of the country have already arrived at the point of believing and saying that regulation properly carried out may not be an unmixed evil, in fact, would probably be beneficial, but they still balk at valuation, without, however, suggesting any other means whereby the general public is to obtain the information on which to base an intelligent opinion as to how such regulation is to be carried out. Mr. Lavis.

The speaker does not for a moment underestimate the difficulties incident to the determination of the intangible values, or forgot the difference between the problem presented by the comparatively new lines in the State of Washington and a valuation of, say, the Pennsylvania Railroad or the New York Central. No one who gives any real thought to the problem pretends that the value of a railroad is the value of its purely physical property; but, because the matter of determining the intangible values is difficult and complicated, is it necessary that we should sit back and fold our hands and say "it can't be done"; that in the whole country there is no man or body of men, or engineers, if you please, with brains and ability enough to solve the problem? As for cost, is it not worth $10 000 000, which is more than $40 per mile for all the railroads in the country, or about three times as much as the cost of the most careful appraisals yet made, to have the question put once and for all on a stable basis, satisfactory to all, if the problem be approached in a fair, broad-minded, common-sense way, by engineers big enough to command the respect of both sides? Aside from the question of rate regulation, is it not worth this much to the railroads of the country to be able actually to prove that the amounts at which they are capitalized are reasonable, as in the great majority of cases they probably are?

There are one or two points which, it seems to the speaker, cannot be too strongly emphasized:

First, that valuations properly made may be the means whereby confidence may be restored, not only in the mind of the general public, but in that of the investor; but, in order to obtain this result, the railroads should urge, with all the power they possess, the necessity of having such valuations made by a body of men, some of whom, at least, should be engineers, big enough to entitle their opinions to the respect of both sides, and thoroughly qualified by training and experience for the work.

Second, that, as far as possible, regulation should be general or national, so as to avoid the complication of dividing all roads at the State lines, and of having different regulations in different States.

Mr. Lavis. Third, that there need not necessarily be any relation between rate regulation and rate-making. Rate regulation can well be confined to rates in the aggregate, rate-making applies to the adjustment of individual rates, and must necessarily be the work of men well versed in all the varied elements which control it and the particular conditions affecting the business of each particular road. The speaker believes that valuations made in this way and with these objects in view will do no harm to the railroads, and will do much to restore confidence and give us the much needed peace and quietness to carry out necessary development.

Mr. Higgins. CHARLES H. HIGGINS, ASSOC. M. AM. SOC. C. E.—Mr. Riggs' able and timely paper is of great interest and worth to all concerned with the matter of values, whether of public service corporation property, or other property; and what engineer is not concerned with values?

One cannot but wish that an index accompanied the paper, as its usefulness would be thereby greatly increased, particularly as, by its arrangement, such subjects as depreciation, non-physical values, etc., are treated of in many different portions of the paper.

The Wisdom of Having a Physical Valuation.—It is hard to understand how any thoughtful person can now doubt this, for we are in a period of regulation and taxation of public service corporations, and the only question is whether they shall be regulated and taxed with a full understanding of the investment involved, or by arbitrary methods, such as the 2 cents per mile passenger rate, which has been so popular in many States, under widely different conditions and irrespective of the cost of the service.

The time would seem to have arrived when the thoughtful public service corporation manager would welcome a fair valuation of the company's property, as protection against legislation conceived in ignorance of the capital invested.

Relation Between Railroads and Other Properties.—The relation between appraisals of railroad and of water, gas, and traction companies is very close, and the same general principles apply. In the former, however, it is complicated more often by the fact that the lines of a railroad extend through many States, with terminals in one or two, and, further, that the railroads have many subsidiary, controlled, or dependent companies, such as coal, lighterage, terminal, car, warehouse, contracting, elevator, stock yard, and supply companies, often owned, wholly or in part, by men in the railroad management. Agreements with these companies may greatly affect the non-physical values, as determined by the methods advocated in this paper, which may otherwise be sound.

Valuation of All Properties.—The author says that the valuation of all railroad properties in the country "would be of interest." It

would be more; it would be of value infinitely greater than the cost. The mere presence of light prevents many vices, and this is as true in corporation practices as in the streets. It is in accord with Dr. Woodrow Wilson's "pitiless publicity"; and, which is, perhaps, more important, it is the basis, or should be, of all legislation concerning the regulation of these great highways. Mr. Higgins.

One and Only One Fair Value.—Nothing in Mr. Riggs' paper is of more value than his insistence that there is one and only one fair value of the physical property of a railroad, no matter for what purpose it is to be used. How futile are the misdirected efforts of those who would have it otherwise, for, no matter what the purpose of the appraisal may be, who can foresee the use that may be made of it when it becomes public property?

Cost of Reproduction.—Cost of reproduction less depreciation seems to be the established method—that recognized by the Courts—for arriving at the value of the physical property. Cost, as the author contends, can only be an element in determining the present value, for the owner of a stone bridge has as much right to any appreciation in the value of masonry as the owner of land has in the increased value of his property; and, though the cost early in the life of the structure is usually near its value, it may lose that position. What relation exists between the value of the Pyramid of Cheops and its cost? Now, as then, our unit measure of value is changing. Cost is certainly of historic interest, but present value is the subject for present uses.

The points in favor of inspection to determine the physical condition of the object to be valued are convincing, where the structure may be readily inspected. Mortality tables mean little without a history of maintenance. With perfect maintenance there would be no physical depreciation.

Maintenance versus Depreciation.—Depreciation and maintenance are interdependent, so much so that some engineers have advocated dropping the term, "depreciation," and substituting "deferred maintenance." A little thought will make this clear. While this term would not apply in the case of a single rail or car, it is not illogical when applied to a system, built and renewed piecemeal and maintained at a certain standard of usefulness, that is, on all well-managed undertakings of magnitude, units are constantly being replaced, thus maintaining a standard of efficiency. This standard, on the entire system, is usually found to be between 70 and 90% of the cost of reproduction. Some items are even improved, and the cost is charged to the maintenance account, such as that referred to in the paper as "consolidation and adaptation" of roadbed; and only a few, such as steel rails, steadily and progressively become less useful, and even these have a bottom value, that of scrap steel. Nor are examples numerous where all the rails are laid at one time, and they are extremely rare where all are

Mr. Higgins.

replaced at approximately the same time. When the rails on a street or section are renewed, the cost cannot properly be charged to capital account, except in so far as the new rails are of a more valuable type than the old ones; for, if this were done, there would be no limit to the capitalization as time goes on. Furthermore, the moment it is admitted that, by reason of a change in the art, we may have depreciation through obsolescence, we admit that through a change in the art we may have appreciation through the opposite of obsolescence. This being the case, the use of "mortality tables" to determine present value is misleading, unless it is done with the full itemized accounts of maintenance, which are seldom, if ever, available. The author's position in regard to the need of inspection of each item is well taken.

Dead versus Live Properties.—These, perhaps, are not happy expressions, but they serve to emphasize a vital distinction which must be made in the valuation of properties. The difference may be as great as between a corpse and a man; here, also, the distinction is hard to define. We say the soul has departed, or the spark of life is extinguished, but these expressions do not contain a satisfactory scientific definition. So, as Mr. Riggs points out, the physical property of a going business may not be valued as so much junk, even if the non-physical values are to be determined separately.

The Franchise a Contract.—The Courts hold a franchise to be a contract, something often forgotten, both by the public and by corporations. The speaker, however, understands this only to mean, even where the franchise is in perpetuity, that the property of the corporation cannot be taken for public use without just compensation. In a sense, then, there can be no such thing as a perpetual franchise. Using the word franchise with its restricted meaning, the unreasonableness of the rates may be measured by the value of the franchise.

Physical versus Non-Physical Values.—The following division has been made by the author between physical and non-physical property, for the purpose of valuation:

"That the Physical Value, or present value of the physical property, should fairly represent the actual capital invested in the property at the date of appraisal; that it should be made up of the sum of the various elements which constitute the cost of reproducing the property together with any appreciation which may have been added to any of them, less all depreciation.

"That the Non-Physical Value is the difference between the 'fair value' as defined by the Courts, or the reasonable value of the property as a business or producing property, and the physical value, or actual present worth; and that the only proper method for determining such values involves a study of income accounts.

"This Non-Physical Value may be: positive, or a value in excess of the physical property, or negative, or less than the physical value. In the case of a property having a negative intangible value, a deduction should be made from the physical value."

Mr. Higgins.

This division is convenient but arbitrary. It is the division of an engineer rather than of an economist; for these so-called non-physical values are like the breath of a man's life; without them, the physical value is like the discarded body. Again, the use of negative non-physical values, while convenient, may not be wholly logical. These remarks are not directed at Mr. Riggs, for he is careful to say that he is dealing only with active enterprises, and not with those which are inert, and the speaker realizes that he is not attempting primarily to build up a logical argument, but to formulate certain rules to overcome practical difficulties met by all who have attempted valuation work. As many who have not given this matter much thought are apt to be misled by the distinction made between physical and non-physical values, they should bear in mind that the line between them is like the equator, an imaginary one.

Water.—"The water is as much a part of the cost of putting that line there as the rails," remarked a corporation official, of admirable character and wide experience, pointing to a trolley line from the window of a Pullman car; and, bearing in mind what he meant by "water," this is undoubtedly so. The cost of promoting the enterprise, the discount on the hazard, the loss of interest during its infancy, the labor of building up the undertaking—these are all real elements of cost, and may remain in the property as value, but, like all other items of cost, they have their reasonable limits, which, in each individual case, can be determined within narrow bounds.

Purpose of a Valuation.—As Mr. Riggs points out, there are four reasons for a valuation: Taxation, rate-making, purchase, and control of the issue of securities, one of which is usually the primary cause for the valuation being made; and he argues that there can be but one "fair value" of the physical property, whichever of these reasons may prompt the appraisal. This is fundamental, for "fair value" is used in the sense of true value, which, to the writer, seems to be a more apt expression. It is rather surprising that it does not appear in the paper. Its use, of course, is old; in the Constitution of New Jersey, 1875, we find: "Property shall be assessed for taxes under general laws, and by uniform rules, according to the true value." Each of the three matters, taxes, rates, and authorized capitalization, are interdependent and, in the long run, cannot be considered separately. This can be emphasized by a *reductio ad absurdum:* Modern civilization is so dependent on transportation by rail that unquestionably all taxes could be raised by assessment on the railroads, if these roads were allowed to fix their rates and were protected in the collection of them; but how would this method differ from that of the Romans, of farming out the collection of taxes? Not materially, and no one advocates a return to that method. This is absurd, but it serves to emphasize the relation between taxes and rates. Taxes can only come from the rates.

Mr. Higgins.

Overhead Charges versus Unit Values.—There is much in various parts of this paper concerning overhead charges, but very little about the items considered in determining the unit values or unit prices used; and does not the latter greatly affect the former? For example, in discussing the Michigan appraisal, the author says:

"For many items, such as clearing, grubbing, earthwork, masonry, etc., the price was fixed by agreement during the discussion at a figure which represented the fair average cost of this particular item during the 5-year period preceding the appraisal."

The "fair average cost" under what conditions? This word "cost" is understood by different men in as many different ways as the word value. Mr. Riggs very clearly gives the items included in "fair value" as finally arrived at by him, but it would seem to be as important to define "fair cost" as used in arriving at the unit prices, for otherwise the chain has a weak link.

What may be considered a fair cost per unit of measure for a particular item differs greatly: First, with the point of view and breadth of horizon of the man stating such cost; and second, with the methods of letting contracts and accounting with which he may be familiar, as applied to such items of work. Because of the first, a fair average unit cost may mean one thing to a contractor, another to a division engineer, still another to a chief engineer, and a fourth to a manager or consulting engineer; and because of the second, the understanding of the term may differ among men of the same class. All of this quite aside from what may be termed the personal equation of the individual. Thus the subject of overhead charges can only be discussed profitably in the light of knowledge concerning what has already been included in fixing the unit prices used. For example, the element of hazard common to all construction, but differing in degree on different classes of work, may be included in the unit cost used, or it may be added as a percentage to resulting sums, but it cannot rightly be included twice. This is equally true of other elements of cost of a similar character.

The foregoing is pertinent, for any valuation will probably be attacked in the Courts, and the unit values will be one of the most tempting points for assault, for the very reason that this wide difference of understanding in regard to cost, and particularly in regard to unit costs, exists. This same difference of understanding is usually the reason for the wide difference in unit costs testified to by able engineers and, consequently, for the distrust often felt for such testimony. The methods followed in taking expert testimony usually work to make "confusion worse confounded." The judge or layman, hearing two engineers testify to widely different unit prices as a fair average cost for certain work, forms a low opinion of their judgment, or worse, whereas the real difficulty may, and usually does, lie in a different

understanding of the meaning of the term "cost," or "unit cost." To the speaker, this seems to be the weakest point in an admirable paper. Mr. Higgins.

Paving.—Whether the value of the paving between and for a space outside of the tracks is an element of value in a street-car line, or whether the cost incidental to the construction and maintenance is in the nature of a tax, is a much disputed point in all valuations of street-railway properties, and an important one, for it may amount to $15 000, or more, per mile. It is interesting to remember that the custom of requiring street-railway companies to maintain the pavement between the rails and for a space of about 2 ft. outside of them, which has become almost universal, developed during the use of horses to draw the cars, the animals causing great wear on that portion of the street. This question of values is a difficult one. It would seem that the most tenable position is that: If the fee to the pavement is not in the company, and if the rule concerning cost of reproduction less depreciation is to be followed, the cost of taking up and relaying the pavement is an element of value in the physical worth of the track, for it would be impossible to reproduce the track without incurring the cost of such work.

S. D. NEWTON, ASSOC. M. AM. SOC. C. E. (by letter).—The general scope of this paper is admirable. The author's views and definitions are unusually sound, clear, and forcibly expressed. To one minor detail, however, the writer is unable to subscribe. Referring to "the physical property element of value," he states that: Mr. Newton.

"This consisted of those things which are visible and tangible, capable of being inventoried, their cost of reproduction determined, their depreciation measured, and without which the property would be unable to produce the commodity on the sale of which income depends."

Take the case of an industrial spur for some minor industry along a line of railroad. It is often a question in the minds of the management whether or not the car-load business done by such an enterprise is sufficient in quantity to warrant the expense of a spur track. There are probably other facilities in the neighborhood which could be used to take care of this business at the expense of some inconvenience; in a large proportion of cases, the railroad will handle the business anyway, and the spur can in no sense be called a necessity. Still, it is visible, tangible, and capable of being inventoried, and should be included in an inventory of the property the same as any track or section of track belonging to the Company. This may also be said of an extra settling basin or filter bed in the case of a water-works plant. If such basin or bed were not in existence, and a leak should occur in the original plant, the business of supplying water to its customers could, in all probability, be carried along in some manner until the break could be repaired; nevertheless, such a tank or bed is desirable, and its value should most certainly be included in an inventory.

Mr. Newton.

Take the extreme case of a piece of machinery which is utterly broken down or so far out of date as to be entirely worthless for the purposes for which it was designed. Yet such machinery has, at least, a scrap value, and as such it should be included in the inventory as part of the tangible assets of the concern at the date in question.

Of course, in many instances, certain interests endeavor to have inventoried items which should either be omitted altogether or included at a much reduced valuation from that sought to be placed on them, and, in such cases, the very best judgment of the appraising engineer must be called into play in order that injustice may not be done to either party; but to say, as Mr. Riggs' definition virtually does, that nothing should be inventoried which can, either with or without inconvenience, be dispensed with, is absurd, and the writer does not believe that such is the meaning the author intended to convey. Probably, if the word "economically" were inserted in the definition, it would more nearly represent the proper idea.

Mr. Polleys.

WILLIAM V. POLLEYS, M. AM. SOC. C. E. (by letter).—In his very thorough and painstaking paper Mr. Riggs states that it is confined to a discussion of methods for arriving at a correct figure of cost, and disclaims any intention of considering the propriety of using said figure when reached.

Inasmuch, however, as he devotes the next eight or ten pages to a dissertation on law, political economy, rate-making, finance, and advice to railroad employees, with a word of encouragement to the good, and firm reproof to the bad ones, it is fair to assume that he intends this disclaimer in a Pickwickian sense, and that the real intent of the paper is to show that the physical valuation of property is, with certain determinative, corrective factors, a proper standard for gauging taxation, bond issues, and kindred evils.

Is it not a fact, however, that taxation is based on a much more intangible structure, and that the net earnings must necessarily have more to do with it than the physical valuation of the property—whether it be that of a wicked public service corporation, or that of an honest haymaker—rather on what their property can produce, than on what it would cost to produce the property? Is it not rather a battle of business acumen between the taxer and taxee, a battle which, among other things, is regulated more or less by the fact that an extreme in either direction will bring disaster to one or both, followed by the inevitable reaction and readjustment?

Take, for instance, an extreme case: A manufactory is erected on comparatively worthless ground. A million dollars or more is invested in a plant, with the result that surrounding real estate values go up with a bound. Supposing that the manufacturer has not made any previous arrangements for immunity, and the assessors are both acute and honest, the property will be taxed for a large figure, which tax,

Mr. Polleys.

if the factory is making money, will be paid, with more or less grumbling, up to the economical breaking point. Suppose that, owing to a sudden permanent change in business conditions, it becomes impossible to operate this plant, and it is abandoned. A corps of experts may be thrown into the mill, before the last employee has left the building, and may carefully scrutinize and caliper the machinery, count the bricks in the wall, tap the stay-bolts in the boilers, and bore into the furniture to see whether it is solid or veneer, and when they are through and their figures are all in, they have not arrived at anything that is of the slightest use as a basis for a bond issue or taxation, and very little that would be of use for sale. In such an extreme (but by no means unheard-of) case physical value bears no relation to real value.

This is not to say that a physical valuation is without worth, and even great worth in some cases; it is merely offered as an opinion that the physical value is in many (and probably most) instances a very treacherous guide to the real value—a far poorer guide, as a general rule, than the accounting department; a minor quantity, in fact.

It seems doubtful whether there is a scientific way of arriving at the true value of a going property by the physical-valuation route. There is too large a percentage of values which, being intangible, are matters of judgment. At best, the determination of value must be that of opinion, and the worth of that opinion hinges principally on the practical qualifications and disinterestedness of the person who gives it.

Unfortunately, or fortunately, as the point of view may be, the disinterested person is not apt to be qualified, nor the qualified person to be disinterested, and it seems extremely probable to the writer that, while weapons may be changed and excuses vary, the tax war will be waged as of yore, and the fool and his money will continue along diverging paths until something more ingenious than physical valuation is invented, however well the valuation may be made.

Mr. Howard.

C. P. HOWARD, M. AM. SOC. C. E. (by letter).—While there may be no material differences of opinion as to the principles on which a physical valuation should depend, such a detailed description of organization and methods as that presented by the author should be of great service to others undertaking similar investigations.

It may not be amiss, however, to mention certain features affecting the non-tangible values which should be more fully considered in any general discussion of the subject.

The author calls attention to one or more particulars in which the methods of the Michigan appraisal may "fail as a method of determining a value for use as a basis of rate-making." Later, after quoting various court decisions, he dismisses this phase of the subject with the words: "In view of these dicta, it is needless to argue whether a rate of 6% or 10%, or 15%, or more, be reasonable."

A value for purposes of rate-making might more properly be called

Mr. Howard.

a "permissible value." The writer holds no brief for the corporations, and would not like to fall under the imputation of being "apparently incited by, either the direct interest of corporations, * * * or an effort to confuse the subject of valuations," but will venture the following, which, while it does not exactly represent any particular case, it is hoped may be recognized as an illustration drawn from life.

A, B, C, and their associates, being familiar with a certain territory, its resources, transportation facilities, and growing development, believe that the time has come to build another railroad through their State or States. They have made careful estimates of the amount of tonnage that may be expected from the development of its mines, timber, farms, etc., and conclude as follows:

First.—The road, completed along the most approved lines, will cost, with equipment, $50 000 000.

Second.—It will take five years to construct and equip the road and put it in fair running order.

Third.—The traffic, when fully developed according to their hopes and expectations, will eventually afford at usual tariffs a handsome profit, say, from 8 to 12% per annum on the capital invested. This condition, they believe, in all human probability, will be attained in from 5 to 10 years after completion.

Fourth.—That half the traffic anticipated will pay 5% on the investment.

Fifth.—They are obliged to admit (though the chances of this are so remote as to be in their opinion negligible) that, due to unforeseen causes, obstruction, competition, etc., there is a possibility that, as has so often happened in the past, the enterprise may prove a financial failure, or that the period of prosperity may be postponed so far into the future as to amount to practically the same thing.

Here is a bold undertaking; but were it $5 000 000 instead of $50 000 000, the conditions would be essentially the same. Nevertheless, they have the courage of their convictions and go ahead.

Now, with all the risks and uncertainties attending an enterprise of this sort, if the ultimate profits were limited in advance to 5 or 6% on the capital invested, less depreciation, who but the Government itself could afford to build a railroad?

Evidently, when an existing railroad makes small additions from time to time to extend or take care of its business, the risk is not so great. Such extensions will continue more or less under any limitations.

For rate-making, it is evident that an appraisal based on earnings will utterly fail of its purpose if made during the lean years immediately following construction. If made some years later, when the property has begun to pay, the risk and necessary financial loss of the lean years should be remembered, as any one building a road in the

future will necessarily have the same problems to meet, together with the expenses of interest, depreciation, loss from operation, etc., both during the construction and the lean years following, all of which must properly be considered a part of the real cost of constructing and developing a property. Mr. Howard.

J. E. WILLOUGHBY, M. AM. SOC. C. E. (by letter).—The determination of the cost of reproducing the property of any steam railway involves, together with other items, an estimate of the present cost of: Mr. Willoughby.

First.—The acquirement of the right of way, to the extent, in the form, and on the location of that held in connection with the railway to be reproduced;

Second.—The construction thereon of the roadway, to the form and dimensions, and of the materials which the roadway to be reproduced exhibits; and

Third.—The seasoning and adaptation of the roadway to the state of perfection which the roadway to be reproduced exhibits at the time the estimate of cost of reproduction is made.

The first conception, for fixing the cost of the several items, is to consider the railway to be reproduced as being non-existent at the time the estimate is made, but having the environment which then exists along the operated railway, although that environment may be largely of the railway's own creating. The cost of the right of way is to be fixed as ungraded and unimproved property attached and forming a part of the adjoining improved property, which adjoining property will be entitled to receive, in addition to the market value of the land taken, all consequential damages due to the taking off of the right of way in the form and location that the land has actually been taken, and for the purpose of railway construction and operation. This adjoining property is to give credit on the consequential damages for the incidental benefits which it derives, if any, from the construction and operation of the railway.

In fixing these values, the drift of public sentiment—the bias of juries of view and of trial juries—at the time the estimate of cost of reproduction is made must be considered, since that sentiment may affect enormously the cost of the right of way. The amount to be paid for a right of way is in the end that which a condemnation court will award. The question as to whether or not the right of way was originally donated can no more enter into the determination of the cost of reproduction, for the purpose of lessening the estimate of cost of acquiring the right of way, than the fact that donations of lands or bonds (or of convict labor and slave labor, as in the South prior to 1860) made by governmental authority or private enterprise, at the time of the original construction, can be used to reduce the reproduction cost of the excavation made in the formation of the roadway.

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No rule as to the sale of property for commercial purposes in the vicinity of an operated railway can be rightfully adapted as covering the line as a whole. While the cost of right of way through farm or timber lands bears a general relation to the value of those for agricultural purposes, where improvements thereon bear but a small proportion to their total value, this relation is wholly wanting in the cost of a right of way through a village or city or at any point where the improvements on the property bear a large proportion to its total value. The relation is also wanting where a right of way is obtained through agricultural lands devoted to special purposes, like that of country homes for the rich. It is also wanting where the right of way is taken out of the narrow river lands in the Appalachian Mountains, where the total value of the whole farm is dependent on the small acreage of flat land along the river bank. The general rule of prefixing a constant to the current selling price of lands, in order to determine the estimated cost of right of way, should be limited to agricultural and timber lands, and to those which, owing to their extent, the carving out of the right of way does not wholly destroy for the continuation of agricultural and timber operations.

For villages and cities, and for lands devoted or adapted to special purposes, an accurate estimate of the cost of reproduction of the right of way can be determined only by a specific investigation of the conditions in each community. While it is difficult to conceive all the activities and sentiments which have growth in, from, and of railway operation, as being in existence without the railway, it is only through such an assumption that one can estimate correctly the make-up of the items of cost of reproducing a railway as such railway may now exist. To assume that the railway, not existent for the purpose of estimating the cost of reproduction, will now receive the donations of land and moneys that were made half a century ago, is merely going back to a determination of what the road has actually cost; and that is contrary to the intent of the theory of the cost of reproduction. The conception of a parallel line is not correct, for it imposes thereby a further burden on properties which have already contributed to the public good, probably to an extreme extent, and gives an abnormal cost for right of way, as shown when a railway seeks to enlarge its terminals in a crowded community, or to find a new entrance into a populous city.

So, too, in estimating on the formation of the roadway, one must consider the roadway to be reproduced as being obliterated—all cuts and borrow-pits refilled, and all embankments and spoil banks removed from the right of way—but all other lines of transportation, except the railway to be reproduced, must be considered as being in existence as they actually are at the date when the estimate of cost of reproduction is made, and that such other lines of transportation are available

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for bringing in machinery, tools, teams, materials, and supplies for the construction of the railway to be reproduced. It is only by such an assumption that the benefit of the improved means and methods of construction now prevalent can be obtained; but it is not permissible to estimate for the construction of a railway with different grades, alignment, roadbed, widths, or with different materials than that of the railway to be reproduced merely because such construction at this day might be actually cheaper or better than to construct it in exact duplication. For example, if the rock cuts on the roadway to be reproduced be only 18 ft. wide, with $\frac{1}{4}$:1 slopes, one must not figure on the greater economy of steam-shovel excavation, because the steam shovel cannot be worked in cuts of that width; nor can the spoil from such cuts be carried long distances to eliminate a possible solid-rock borrow originally made elsewhere, because long hauls are practicable in steam-shovel work, but wanting in excavations where the mule is the transportation force. So, too, it is not permissible to estimate on reinforced concrete bridges to take the place of more costly cut-stone arches, if cut-stone arches are the structures that have been actually built. The idea of cost of reproduction is not synonymous with the idea of the cost of building a railway capable of serving the same transportation purpose. If all our railways were to be built anew, in the light of our present knowledge, and with our present traffic offerings and financial resources, vast changes would be made in the character of construction. The physical fact of existing construction prevents a theoretical substitution of what is the best construction for any community, together with its costs for the construction which was actually made years ago.

In the event that an estimate of reproduction costs be made for a State as a whole, or for a great railway system as a whole, the conception of reproduction is modified so that the construction may take the form of progressive construction, the principal lines being built first and the less important lines afterward. This method will require the estimate for interest during the construction period to be greater.

The money cost of the seasoning and the adaptation of the roadway to such a condition as will permit heavy trains to be run at high speeds, is great, but the amount is not readily ascertained. An estimate of cost of reproduction, to be true, must consider this item; and probably the more usual method of ascertaining it is to assume it to be an amount in some proportion to the cost of the excavation. This proportion will vary with the character of the material through which and of which the cuts and fills are made, and with the methods of construction necessarily adopted. There are many railways on which this cost will exceed 25% of the total cost of excavation.

After the estimate has been made, including the item for seasoning

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and adaptation, there should be added a contingent fund to cover the omitted work, consisting of small borrow-pits and ditches, undetermined foundations, unexpected conditions encountered, unavoidable "force account" work, minor changes of streams and highways, damages to adjoining lands due to the methods of construction and to diversion of water, etc. This item will not exceed 5% of the cost of the roadway if the estimate be accurately made.

The more convenient form into which an estimate of cost of reproduction of a steam railway is to be put is to follow the sub-accounts, as prescribed by the Interstate Commerce Commission for Expenditure for Road. Each item given in that accounting has a place in the estimate. These comments are confined to the items covering the roadway, namely, Right of Way and Station Grounds, Grading, Tunneling, Bridges, Trestles, and Culverts.

Mr. H. C. Adams.

HENRY C. ADAMS, ESQ.* (by letter).—To the writer this paper seems to be the most complete and comprehensive discussion of the general question of valuation of property invested in public service industries that has come under his notice. It is especially important in that it is a summary of the discussion on this most difficult subject during the past ten years, and the writer thoroughly agrees with the general conclusions reached by Mr. Riggs.

There is one point, however, which might possibly have been developed more completely, and that is the treatment of discounts, which presents itself from time to time in the general discussion. Mr. Riggs quotes with approval the following:

"If a company can market its 50-year, 4 per cent. bonds at 90 per cent. of par, it means that the company's credit is on a 4½ per cent. basis; that it could market a like security paying 4½ per cent. at par."

This is, of course, correct as far as the mathematics of the proposition is concerned, but it seems to overlook that peculiar psychology of the market which enables a corporation to secure a larger amount of actual cash for a given interest annuity when bonds are sold at a discount than when they are sold at par.

Aside, however, from the accuracy of the above quotation and of Mr. Riggs' apparent acceptance of it as the final word on discounts, one may ask if it recognizes all the elements necessarily involved in a discussion of the problems raised by discount financiering. From the literature of the subject one may read the following claims: Discount is a measure of the risk involved in a new enterprise; discount is a market adjustment that reflects the current value of money; discount is a sacrifice of principal for a slightly reduced interest annuity; discount is a dividend declared before the dividend is earned; and

* Professor of Political Economy and Finance, University of Michigan.

many cases are cited in which a discount is merely a promoter's fee for services rendered. Mr. H. C. Adams.

The writer does not care to discuss at this time these various points of view from which discounts may be regarded. They are mentioned merely to suggest that the subject is not as simple as some writers seem to think. Any valuation of public service industries, from whatever point of view it may be regarded, must, from the nature of the case, touch the problem of fundamental equities; and one of the elements of this problem which has not as yet been fully analyzed is this element of discounts. From the point of view of taxation, such an analysis is not perhaps essential; but if the valuation is to be used as a basis of determining reasonable rates, or as a measure of reasonable capitalization, it seems to be essential.

The writer is sure this discussion will not be construed as in any sense a criticism on Mr. Riggs' paper; it is rather a suggestion of an unwritten chapter in the literature of valuation. The American Society of Civil Engineers is to be congratulated in securing from one of its members so complete and satisfactory a discussion of the principles and methods for the valuation of public service corporation property.

CARL C. WITT, M. AM. SOC. C. E. (by letter).—The appraisal of the railway property in Michigan was a wonderful performance in a great many ways, not the least of which was the thoroughness of the work, considering the short time available, and the writer desires to express his appreciation of this paper, as it is a valuable addition to the meager literature on this subject. Mr. Witt.

More recent appraisals, made by States traversed by the same railway systems as those involved in the Michigan appraisal, have been made with a freedom from opposition by railway companies due to the educational effect of this pioneer work. Particularly is this true of the recently completed appraisal, by the Board of Railroad Commissioners of South Dakota, of the physical property of the railways in that State, of which work the writer was the Engineer in charge. No opposition was met; in fact, some of the railway companies had established regular departments for furnishing inventories and appraisals, had completed the necessary field work in South Dakota before the inventory had been requested by the State, and were able to furnish a very complete appraisal in a short time after the request for it was made.

This appraisal was made in compliance with an act of the Legislature of 1907, which required the Board of Railroad Commissioners to ascertain the true cash value of all the property of every railroad company in South Dakota used in the operation and maintenance of their respective roads. No attention was paid to the purpose of the appraisal, but one of the first uses made of the information thus secured

Mr. Witt. was in the litigation following the passage of an act by the Legislature of 1909, prescribing a maximum passenger fare of 2 cents per mile on all railroads operating within the State. In connection with a rate case of this kind, some questions have been raised regarding proper bases for land values, the use of an item for adaptation and solidification as an element of physical value, the value of the intangible assets, etc.

The lands of all railway companies were appraised at a cost to reproduce or re-purchase at the time of appraisal, regardless of the original cost of the property. The sales method was used for determining the market value of adjoining property. There has been a very large land movement in South Dakota in the last five years, and as most of the country is prairie, with similar soil over large areas, it was not difficult to determine the average market value of the land for farm purposes, at the date of the appraisal, and the gradual trend of values for five years previous to that date. An average multiple of 250% was used to arrive at the cost of reproducing or purchasing the right of way. This multiple was based on investigations made of recent right-of-way purchases, and inasmuch as there are no large terminals in South Dakota, the same average multiple was used throughout the State for both town and farm property, investigation showing that town property could be secured for slightly less and farm property for slightly more than the average multiple used.

In each supplemental appraisal the land values will be corrected to correspond to the changes in surrounding values, as the railway company is entitled to any increase, due to natural causes, based on the cost to reproduce at the time of appraisal. This is a well-established theory, as shown by Mr. Riggs.

No allowance was made for the item commonly known as "adaptation and solidification," except in the item of contingencies and in the consideration of the present value of the ballast. In some recent appraisals, large sums, based on a percentage of the cost of grading, have been allowed for this item. While there is no question that large sums of money are expended in maintaining a safe track on a new bank, and that this expense gradually diminishes as the roadbed becomes solid, due to the pounding of the trains and the action of the elements, this expense is, and properly so, charged to maintenance, and is paid for out of the operating revenues. Now, in the trial of a rate case, exhibits showing the operating expenses, including maintenance charges, are introduced, and to include this same item in the appraisal of the physical property leads to a duplication, for if the passenger or shipper pays for this maintenance charge, it should not be counted as an item of physical value as a basis for determining what is a reasonable rate.

The case is similar to that of a locomotive: When new, it is kept in the vicinity of the shops, because trouble from lack of proper adjust-

ment and weak parts is likely to develop, and the maintenance charges may be much higher than a few months later when the machine has "found itself" and, as an operating machine, is more efficient than when new. However, no one will insist that it has an added physical value in dollars and cents, or that the excess cost of repairs and maintenance during its early life should be added to its cost of reproduction now; in fact, it is a second-hand machine, and the maintenance charges must be paid for out of its use. Mr. Witt.

Generally, when a roadbed is turned over to the operating department by the construction department, it is in good line and surface, and if an appraisal were made at that time its condition would be 100%; but as soon as it is placed under traffic, it begins to depreciate, as shown by the fact that it requires constant attention to keep it up. If the roadbed is cross-sectioned at each station and actual quantities calculated from cross-section notes, there would be no depreciation, but if the grading quantities are calculated from profiles of the line, as constructed some time previously, and for a standard width of sub-grade, with a percentage added for shrinkage, and allowance made where banks have been widened, etc., it will probably be found to exceed the actual measured quantities, because the action of the elements in washing the slopes, the wearing of the shoulders of the embankment due to foot traffic, etc., will show some depreciation in quantities. It is common practice to carry the item for grading over to the present-value column at 100%, or, with no depreciation. This practice, together with the present condition of the ballast due to maintenance, and that part of contingencies which covers washing of slopes, filling of ditches, sink holes, etc., certainly takes care of all adaptation and solidification which should enter into a valuation of physical property.

No appraisal was made of the intangible assets. A great many arguments have been advanced for and against such an appraisal, and in South Dakota it was held that the earning ability of any corporation due to its franchise, strategic location, efficient organization, going-concern value, etc., while perhaps an element of value to be considered in a transfer of the property or if assessed on an income basis, should not enter into a valuation which would be used for determining a just and reasonable return on the investment, because the greater the earning power the greater would be the return, and that this condition would produce a never-ending increase in returns; whereas, when the returns reach a point at which they will not only pay a fair dividend on the investment, but take care of any depreciation in the physical condition of the property and make all needed improvements in roadbed, buildings, and equipment, demanded by the traveling public, shippers, increased traffic, or natural causes, they should be kept to that point. There are several hundred miles of railway in South Dakota which have been built out of the surplus

Mr. Witt. earnings of the parent corporation—in other words, with money supplied by the traveling and shipping public—but which are owned by the railways and on which they may earn another surplus for constructing more extensions, etc., etc.

The original South Dakota appraisal, as of June 30th, 1908, on forms similar to those used in Minnesota, has been supplemented by yearly appraisals corrected for all additions and deductions made during the fiscal year. For this purpose a new set of forms* was prepared, with the various items classed in accordance with the "Classification of Expenditures for Road and Equipment," as prescribed by the Interstate Commerce Commission, and arranged so as to facilitate showing the yearly changes.

Mr. Thompson. R. A. THOMPSON, ASSOC. M. AM. SOC. C. E.† (by letter).—This paper is considered by the writer to be the most complete treatise ever written on the valuation of public service corporation property, and the author deserves the sincere thanks of the entire Engineering Profession and all others interested in this most important question. Its presentation is most timely, in view of the agitation, particularly on the subject of railroad valuation, which is now engaging the attention of Congress and the law-making bodies of the several States, as it contains much valuable information relative to decisions of Courts, in addition to clear and concise expositions of the methods in vogue for the appraisement of corporate property, etc.

It is a fact—rapidly coming to be recognized by legislative and judicial bodies—that the prescription and regulation of tolls, charges, and assessments against public corporations cannot be made systematic and intelligent unless there is provided some estimate of the value of the property involved, based on the cost of its replacement or reproduction. Particularly is this true of railroads; and such regulation of the affairs of these corporations as has heretofore been essayed by State and National commissions, has generally been on illogical bases, unsatisfactory alike to the proponents and the companies. Results have been had, it is true, after a fashion, but there have been endless disputes and litigation, with the prime questions involved no nearer solution than before. One has but to contemplate the varied and often antagonistic legislation promulgated by the several States, relating to corporation management, and the many rulings and decisions of the different courts and commissions on the subject of regulation, assessment, and adjudication of corporate rates, revenues, taxes, and tolls, to become convinced of the complicated and tangled condition of the situation, and to realize the necessity for the early establishment of some logical basis on which to establish the fabric of corporate control.

*For convenient reference, a set of these forms is filed in the Library of the Society.
†Now M. Am. Soc. C. E.

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While it is not maintained that an appraisement of the physical property of public service corporations will be the panacea for all such ills, the writer firmly believes with the author that such appraisal, as a beginning, is absolutely necessary, and when effected on some fair and reasonable basis, will contribute largely to the successful solution of many of these intricate problems.

With the estimate of the physical value of a property before it—which represents money actually invested, together with such accruals to costs as it may be determined that the owner is reasonably entitled to have considered—any Court, tribunal, or commission is in a better position to mete out impartial justice, whether it be the regulation of a rate, the assessment of a tax, or the imposition of a fine.

Although the author's experience in valuing corporate property has been principally in connection with the Michigan appraisal of railroads, and to him is largely due the credit for devising methods for, and carrying forward to successful completion, this thorough and most excellent work, it is refreshing to note his inclination to give credit to the work of others along the same line in other States, which, it is to be regretted, has not always been the case with writers on this subject. There is no doubt that the work of the Michigan and Wisconsin Boards of Appraisal—conducted under the advice and direction of some of the most eminent and talented engineers and economists in the United States, and practically without regard to expense—is the most complete and perfect of its kind heretofore attempted; yet there are many features in regard to the organization and execution of its details about which there may be an honest difference of opinion, as viewed by those who have been similarly employed.

It is but natural—as suggested by the author—to find the "individual" character of the appraiser (which has been moulded by his environment, training, and former service) reflected in his opinion, and this would be most probable in the organization for, and carrying on the work of, appraising a railroad property, which involves consideration of practically every phase of engineering and economics. The judgment of any man is essentially warped along the lines of his experience, and he is necessarily biased and prejudiced in favor of or against certain practice. As a consequence, therefore, it is not reasonable to suppose that any one man, or set of men, can formulate a system for valuing corporate property which will be perfect in all its details, and be free from objection and criticism.

The writer was employed for a number of years as Engineer for the Railroad Commission of Texas, and had charge of the valuation of railroad property under the Railroad Stock and Bond Law of that State. A paper on the methods used by this Commission was prepared by him and published by the Society.* This Stock and Bond Law was

*Transactions, Am. Soc. C. E., Vol. LII, p. 328.

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enacted in 1893, and the railroads then existing were valued in 1894 and 1895. The average value of 8 860 miles was $15 844 per mile. This valuation was made by Charles Corner, M. Am. Soc. C. E., now Resident Engineer of the Rhodesia Railways, South Africa, and Mr. H. J. Simmons, now General Manager of the El Paso and Southwestern Railway System. The actual cost of this work is not available, but is estimated at about $2 per mile. The engineers making the appraisal secured maps, profiles, and all available information from the offices of the railroad companies, including all the construction records and estimates of quantities which were preserved. Appraisal was made only after one of the engineers had made a personal examination on the ground, accompanied by assistants to aid in measuring structures and estimating quantities.

All valuations made since 1895 have been of new railroads making application for issuance of securities, and in all cases the deeds for right of way and depot grounds, the contracts for construction, the actual quantities of construction of all kinds, the plans and specifications for all structures and construction, and all other information which the engineer desired, were submitted by the railroad companies to enable an accurate appraisal of the value of the property to be made. It is not possible for valuations of this character to be made under more favorable circumstances. Up to October, 1909, more than 3 500 additional miles had been valued, and in all cases the estimates limited the securities which the companies might issue.

Writers on railroad valuation have generally been inclined to discredit the work of the Texas Railroad Commission and the system of appraisal used by it. One writer, of more or less prominence, has referred to it as the "cheap" method. While it may be true that other appraisals have been more expensive, it is a fact that those of the Texas Commission have served their purpose well, and the railroads, as a rule, have made little complaint. As a matter of fact, it is highly probable that the valuations of railroad property made by the Texas Commission have been of greater utility, as far as the public is concerned, than those of all other States combined, and, at the same time, no injustice has been done the railroads.

It appears that those who have interested themselves in investigating the Texas method of railroad valuation—including the author—have failed to construe the real meaning and intention of the Stock and Bond Law. Apparently, it was passed for the purpose of limiting railroad indebtedness—and is referred to by Mr. Riggs as serving only this purpose—but while its effect has been to accomplish this most successfully, its enactment carried with it a deeper significance.

This law was passed at the same time as the General Railroad Commission Act of the State, which gave to this Board absolute control over all freight rates and tariffs, and also other powers not possessed

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at that time by any other State commission. The decisions of the highest Courts at that time laid stress on the right of carriers to maintain rates which would afford a reasonable return on stocks and bonds outstanding. Hence, to delegate the regulation of rates to any tribunal by any law which did not carry with it also the right to supervise and restrict mortgage indebtedness to some reasonable extent, appealed to the legislators as being essentially ineffective. The effect of the law has been to reduce steadily the average outstanding stocks and bonds of the railroad companies of the State from an average of $40 802 per mile in 1894 to $31 910 in 1909—and this, too, in the face of a recognized increase in the physical value of the properties—thus depriving the railroads of one of their most potent weapons of offense when contending against the Commission's orders. It is a matter of common knowledge that the indebtedness per mile of railroads of other States has increased greatly during this period. It is also a fact that the railroads of Texas have, except in rare instances, contended that injustice has been done them in the enforcement of this law, and the market value of their stocks and bonds has steadily risen. Also their physical condition is on a par with that of railroads in other Southern and Western States, and their incomes from operation are as substantial. The practice of "watering" their securities has been effectually stopped, as regards local issuance, and any interest which might have accrued on such securities has been saved to the public.

It has been contended that the Texas valuations of 1894-95 were too low, and did not, even at that time, represent the fair value of the properties. This is perhaps true to a certain extent, but it must be remembered that the costs of materials and construction then were less than at any time before or since; and, viewed from the present-day standpoint, they seem to have been inadequate. It must also be considered that real estate values throughout the entire State were very low, compared with present values and with those of lands in other States. Although the writer admits that the margin was very narrow, still he is of the opinion that the valuations as made represented closely the cost of reproduction of the physical properties at the time.

The valuations of 1894-95 stand to-day on the Commission's records as "the value of the property," except in cases where there has been application and necessity for re-valuation. The machinery of the law did not provide that these appraisals should be kept "up to date." The mortgages on these railroads are still outstanding, and there has been no call for another appraisal, except in a few instances. The Commission has decided that in its opinion the "present value" of any of the railroads already appraised is represented by the original valuation plus the value of all permanent improvements and betterments added. This principle has been carried out with those railroads which

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have applied for re-valuation for any purpose, and the Commission has admitted the same in testimony which it has given before the Courts.

Since the appraisals which the Texas Commission makes are primarily for the purpose of limiting indebtedness, and the carriers are entitled to have these at least equal the cost of their property—the investment with certain additions to cover promoters' profits—no consideration can be given to depreciation of structures and equipment, although the application for valuation and process of issuing of securties may be had several years after completion. The writer holds that there is strong argument in favor of not taking into account "depreciation," and of estimating the value of the property as being entirely "new," whatever purpose the valuation is proposed to serve. This is apparent, as already stated, when the valuation is to serve as a basis for limiting the issue of stock and bonds. Is there any logical reason why a valuation for this purpose should not also serve—as far as it pertains—as a basis for taxation or for regulating freight rates? As far as the State is concerned—and to be consistent—should not "one" valuation serve all purposes?

Suppose that a State should create a board clothed with powers of rate regulation, taxation, and authority to restrict indebtedness, and also prescribe that it should appraise the value of the property of the railroads, and use that appraisal as the basis for its acts. Would it be logical for that board to make and apply one system of valuation for one purpose and another system for another purpose? Manifestly, it would have declared that a valuation was a "valuation" for all purposes, at least as far as the physical property was concerned; and, when devising a method for making its appraisals, it should incorporate therein all the elements of value which might apply logically to either purpose. The writer believes that "depreciation" of roadbed and structures would have no place in such an appraisal, on the one hand, nor its negative, but fully as intangible and difficult of concrete estimate, "adaptation and solidification of roadbed," on the other.

It should not be understood that the writer maintains that taxation boards should not go beyond the valuation of physical property to arrive at a final basis for assessment. There are certain intangible elements which should be taken into consideration when taxing property, chief of which is the net income. It is only as far as physical valuations apply in either case that he considers that there should be uniformity.

He does not approve at all of incorporating in an estimate of the physical value of a railroad property such an element as "adaptation and solidification of roadbed," which is credited with so much importance in the Minnesota valuation. In the first place, such an

element is incapable of being measured in tangible terms and reduced to a dollars-and-cents basis; second, it cannot be reproduced in the sense that other property is reproduced, and its value does not appear in the capital account of the railroad; and third, it results from the action of the seasons on the one hand, and the working over of the roadbed by the maintenance forces on the other, the cost of which appears in operating expenses. One is constrained to believe that the engineer who insists on incorporating such an element in an appraisal of the physical value of a railroad is hard put to find material with which to swell his estimate. When noting the large difference in value per mile of the railroads of Minnesota, as compared with those of Michigan and Wisconsin—adjoining States—it would appear that undue prominence had been given to this and similar factors. Mr. Thompson.

The writer's experience as appraising engineer for more than 10 years with the Texas Railroad Commission, and for the past 2 years as a construction engineer—having built about 160 miles of railroad in Oklahoma and Texas—confirms his belief that, in the absence of actual figures of cost, right of way and other railroad real estate should be appraised at but little in excess of the market value of abutting property. The practice of the Texas Commission has been to add from 25 to 50 per cent. The conditions under which railroads were built in Michigan, Wisconsin, Iowa, and Minnesota cannot have been radically different from those in the Southern and Western States. In Texas it has been a rare instance when a railroad has had to purchase all of its right of way. Also, contiguous lands have greatly increased in value since the advent of the railroads. It would appear highly illogical to advocate that these increased values should be multiplied by 3—or even 1½—and used as a basis for taxing the railroads on the one hand, or taxing the public on the other, by permitting indebtedness to be issued against it, the interest on which the latter must pay. The railroad recently constructed by the writer traversed fertile and thickly populated areas, already quite well served with transportation facilities. Only a small fraction of the necessary real estate was purchased by the railroad company, and only in a few cases of such purchase did it pay largely in excess of the market value of the land—and these were where the road interfered with houses and other farm improvements. In cities and towns, land was acquired at practically its fair market value. For rural property, the ratios used by Professor Taylor in the Wisconsin appraisal appear to be quite fair, but in cities they are too high—especially for the Southwest. The Minnesota ratios appear to be unreasonably high.

Any appraisal of the physical value of railroads—in the absence of figures as to their actual cost—is necessarily only approximate, and is correct only within certain limits. Especially with regard to the old roads, where original cost data cannot be had, the values applied

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to property and construction must be largely speculative. It is impossible to build two railroads in the same territory, on the same specifications, for the same amount; yet, on the basis of cost of reproduction, an appraisal board must apply the same value to each.

The writer believes that unless there is more uniformity as to methods of valuing corporation property, as between the States, all valuations will be more or less discredited, as they should be, by the Courts. It is to be hoped that this paper will be generally discussed by the Profession, and will lead to the adoption of more uniform methods.

Mr. Ledlie.

CHARLES H. LEDLIE, M. AM. SOC. C. E. (by letter).—The following is suggested as a method of procedure for determining the fair and equitable value of a property:

1st.—Examine carefully the statutes governing corporations of the class under examination.

2d.—Form an opinion as to whether or not the locality can support such a property, by inquiry regarding the different businesses carried on, bank clearings, railroad facilities, what the surrounding country produces, etc.

3d.—Find from the archives of the company a general description of the property, from its conception to the date of appraisement.

4th.—By close examination of the minute books, directors and executive committees, there can be ascertained all the details of organization, issuing of stock, bonds, and other forms of indebtedness, contracts for equipment, supplies used in the construction, etc.

5th.—Obtain from the general manager or the superintendents an explanation of the details of operating and maintaining the property, including the different classes of service, rates, etc.

6th.—Go over the property, examine it carefully, and talk to any and all employees from whom it is thought that any information can be gained.

The foregoing will give a general knowledge of the property under examination, and will enable one to begin the real work. The examiner's assistants must be competent and experienced men.

7th.—Examine all the vouchers, from the beginning of the company down to the date it began operation; classify their contents under the respective heads for the different classes of material used in the construction, for example, pipe, engines, cable, etc.; then prepare blank tables for each heading, having columns for size, quantity, prices, and total; and abstract each voucher. Do the same with the vouchers for labor, general office salaries, general expenses, interest, taxes, legal, etc. This, when completed, will give the detailed cost, as shown by the vouchers.

Next check the vouchers back through the books, and draw up a statement, which will show the total book cost and, no doubt, will

differ from the voucher total. It is likely that many items will be found for which no vouchers exist, a list of these is made and if the officers cannot give a satisfactory explanation of any of them they are omitted. The total of what remains is added to the voucher total and represents the cash expended for the benefit of the original property, as shown by the books and vouchers. Mr. Ledlie.

8th.—Take all the remaining vouchers of the company (it is supposed that the examiner has already been informed by the officers, and by his inspection of the records, of the extensions and betterments which have been made), separate the vouchers for materials, labor, etc., from those on operating, etc. Next classify them by years, and then proceed as set forth in 7th, and add the different yearly amounts to the total of the original plant. This will show the amount of cash expended (according to the vouchers and books) on the property, for its physical plant, organization, etc., from its beginning to the date of appraisement.

Every examining engineer should know (or can obtain) the prices for materials, labor, etc., during these periods of original construction, extension, etc. If the prices are the same, or about the same, as at the time of purchase, the above total stands as the cash expended; if there should be much difference—and sometimes there is—take the detail of the materials as found in the vouchers, affix the proper prices, and do the same with labor, etc., and this total will be what, in the judgment of the examining engineer, the plant should have cost. A mean between this latter total and that in 8th is taken, in order to be fair and equitable. This amount, in place of that given by 8th, is then used as the cash expended on the physical property. If no difference is found in prices, then the total cash as shown by 8th is considered as the total to be hereafter used.

9th.—A careful detailed inventory is now made of the physical property as it exists at the date of examination. This often requires some excavation in order to determine sizes, quantities, and conditions. The prices used to ascertain the total of the inventory are made by taking the average of all those paid for materials, labor, etc., of the same class, during each year of the property's existence. (The writer considers it manifestly unfair to use the current prices in this calculation, for they may be very much below or above those actually paid, and in either event an injustice would be done, whereas, if the average prices are used, the examiner cannot be accused of unfairness.) To this total cost, as shown by the inventory, 5% is added for engineering and superintendence; 3% for general office salaries, 2% for general expenses, 1½% for legal and organization expenses, and from 5 to 10% for contingencies. (This latter percentage depends on the judgment of the examiner, who, after studying the local conditions carefully, can determine from his own experience what dif-

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ficulties have been met in the construction. It is not believed that a hard-and-fast rule can, in equity, be laid down for this latter percentage.) This total represents the value of the tangible property, based on the inventory. The inventory cost and that set forth in 8th (or possibly as modified by prices current when the plant was built) are averaged, and this result, plus the supplies on hand, is the fair and equitable amount of cash which has been expended on the property. This is used in finding the "Fair and Equitable Value."

10th.—Next take the inventory of the plant set forth in 9th, affix the current prices at the date of appraisal, and to this total add the same percentages for engineering, etc., as set forth in 9th. This gives the cost of reproducing the property, with the same classes of materials, size and make of engines, etc., as is now in it, to which total add the cost of materials on hand for the total of cash required to be expended at current prices to reproduce the plant as it exists.

It is often found that this latter total is greater than that set forth in 8th, for the reason that the engines, etc., may be of types which are now abandoned or obsolete, and the manufacturing company, having to make patterns, etc., would charge more for them than the original price at the date of purchase.

This reproduction cost at current prices is only to give the examiner information he may or may not require later in the investigation to determine some point that might arise in ascertaining the "Fair and Equitable Value."

The writer considers it unfair to call the reproduction value the cost of a modern plant which will give the same service and output, because one is not dealing with the value of a modern plant, but with that of an existing property.

11th.—From this cost (using the detailed inventory to find the extent of property still in existence), calculate the amount of depreciation for each section of the plant, this being based on the present condition of the different parts and what their future life may be. The total depreciation is then deducted from the result found in 9th, and this remainder is used as the "Fair and Equitable Value" of the tangible property at the date of appraisal.

The intangible value (called by many names) must now be determined. It consists of rights, from the State, county, city, or any one or more combined, which the company must have in order to carry on its business. These rights in nearly all States are taxable, and taxes are collected on them. The Supreme Court of the United States has in the past held that they are property, notwithstanding what State "Courts and Commissions" have set forth on this subject, and in the writer's examinations they will be treated as property until the Supreme Court of the United States decides otherwise.

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There are in general three classes of franchises, namely:

I.—Those granted by the State to conduct a business, where no county or city franchise is necessary, only requiring the company to obey the ordinances for excavation, etc. The charter of the Laclede Gas Company, of St. Louis, Mo., is an example of this class.

II.—Those granted by the State to carry on a business subject to a county or city franchise.

III.—Those granted by a city to an individual, singular or plural, or a company, to do business within its limits or a section thereof.

In each case the right may be a contract, for it may require a payment for the franchise granted, either in a lump sum or in yearly installments, or in the form of services rendered, such as for light, etc., free service of some kind, or a combination of any two or all of them.

The manner of determining the value of "Intangible Property" is as follows:

(*a*) The gross collected earnings are audited for each year during the period the company has carried on its business. The same is done for all vouchers, *i. e.*, operating, maintenance, salaries, legal, general expenses, interest, insurance, and taxes, and includes every item disbursed. Whatever this latter amounts to, is deducted from each year's gross earnings as already found, and the result is the true net earnings or deficit for each year.

(*b*) The true net earnings are added together and the mean taken; if, in the period from the beginning to the date of appraisement, any deficits are found, these are deducted from the total of the plus-earnings, the result is divided by the total number of years, and this gives the true average net earnings. This is then capitalized at the legal rate of interest of the State in which the property is located. The result is used as the value of the "Intangible Property."

12th.—The amount given by 11th is added to the result obtained by 9th, and this total is the "Tangible and Intangible Value" of the property, and the "Fair and Equitable Value" of the property at date of appraisement.

If it is found that grave mistakes in design or judgment have been made by not employing competent people, and money has been wasted in construction, the plant is re-designed, for the original plant, and its cost estimated. The same is done for each extension, using the prices paid at the different periods, and this result is used in place of 9th, as the cash cost at the date of appraisement.

In determining the intangible value, if it is found that the management has been careless in order to make large net earnings, at the expense of the physical property, estimates are made of what the

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property can be operated and cared for (here the practical knowledge of operation, etc., is necessary), and these results, plus taxes, etc., are subtracted from each year's collected earnings. The mean or average of these results is considered as the true net earnings, which are capitalized and added as set forth in 12th.

The writer holds that consumers or purchasers should not pay for avoidable error or ignorance, and the amount of the securities issued on the property is not considered as entering into the matter of "Fair and Equitable Value"; when they do, the method is somewhat different.

The mean true net earnings are used in determining the intangible value, because franchises have average values, as earnings and expenses fluctuate in corporations, and, when intangible values are to be considered, they must not be based on the last year's net earnings, for if they are, they may give a very large result in one year and a small one in the next; therefore, to be fair, the mean true net earnings should be the basis of the intangible value. If the company has been over-capitalized, and no sinking fund or depreciation has been set aside, it is the present owner's misfortune. If the company calls something a betterment, and it is found that the betterment has only replaced something, it is not allowed, but is classed as maintenance; on the other hand, if the replacement is larger, and capable of rendering greater results, such as a larger engine, pipe, cable, etc., the cost, less the cost of what it replaces, is allowed as a betterment, and if the old part is sold the proceeds are deducted from the betterment charge, for if it is credited to maintenance, it increases the true net earnings. This is often done, but is not the correct way to treat the matter, for it increases the intangible value.

13th.—When new rates are to be established for a period of future years, the manner of determining the "Fair and Equitable Value" is the same as has been heretofore set forth. The new rates are based on averages, and the first step necessary is to ascertain what gross revenue the company must have in order to pay all classes of operating expenses, maintenance, depreciation, taxes, interest on the "Fair and Equitable Value" of the property, and a reasonable profit.

To obtain this amount, the procedure is as follows:

(*a*) Find the percentage of increase of the operating expenses for each year over the prior one, for a period of generally five years preceding the date of examination (a longer time may be taken if, in the opinion of the examiner, it is necessary), and then ascertain the average annual increase of the percentages. The result thus obtained is taken as the increase percentage for the operating expenses for the new period of time.

(*b*) In order to determine what the operating expenses will average during the time the new contract is to run, take the amount of the

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last year's operating expenses as a basis and add to it the percentage found by (*a*). This total is the operating cost for the first year of the new contract. The amount for the second year is found by adding to the cost of the first year the percentage found by (*a*), and so on for each year of the new period. These results are added together and their average is then used as the mean cost of operation for each year during the full period.

(*c*) The same method is followed for maintenance and taxes, in order to find the average maintenance and taxes for the new contract's life.

(*d*) Depreciation on the plant begins from the date of appraisement, and is estimated on the physical property by using for each section the percentages used in determining the "Fair and Equitable Value."

(*e*) Interest at the rate of 6% is allowed on the "Fair and Equitable Value," and 6% profit.

The question of extensions and betterments to the original plant must now be taken into consideration.

(*f*) The amount of the betterments and extensions have already been found for each year of the property's existence, and an average of them is taken as the amount the company will spend on extensions, etc., during each year of the new contract. On this sum 6% interest and 6% profit is allowed, and, for depreciation, the same percentage as used in the original plant.

It will be seen that all the expenses of operation, etc., of these extensions have been allowed in (*b*), where the increase has been added for each year for these extensions and betterments, as they are assumed to increase the cost of operation, etc.

(*g*) The amounts found by (*b*), (*c*), (*d*), (*e*), and (*f*) are now added together, and to the sum 5% is added for interest, taxes, operation, etc., which may be caused by the necessary increase in capital expenditures, for a greater growth than could be foreseen at the time the new rates were established, for losses, etc. This total is used as the basis for establishing the new schedule of rates.

14th.—The next step is to determine what part of the amount found by (*g*) must be paid by the different classes of consumers.

(I) First ascertain the yearly percentage of increase in the output of the plant for the five years before the new contract is to go into effect (or longer if, in the opinion of the examiner, it is necessary); then find the average increase of percentage during the beforementioned five years. Add to the last year's output the percentage found above, this result representing the output for the first year of the new contract. Continue this operation for each year in the same way as the operating expenses were found in 13th (*b*). The

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average of these results will be the average estimated output during the life of the new contract.

(II) Next find the amount of the total output each class of consumers used during each of the five years, and then find the average yearly use during this period. Put these into percentages of the amount of the average output for the five years, and then use the percentages as the amount each class of consumer will use of the average output found in (I) during the period of the new contract.

This gives the average amount of the output each class of consumers will use during the average life of the new contract.

(III) Next find the average percentage of the total revenue each class of customers paid during the five years. Take these percentages as the average percentage each class will pay of the average revenue necessary during the time the new contract is to run.

(IV) Having found the average amount of the required revenue that each class must pay, and the average amount of the total output each class will use, dividing the former by the latter for each case will give the rate each class is to pay during the new period.

It is often found in plants that large extensions have been made to supply a special contract for a long period of time, and these extensions are set aside for the exclusive use of this contract. In such cases exclude the cost, etc., of this part of the plant from the "Fair and Equitable Value" in the matter of adjustment of rates.

In determining the operating expenses, etc., in such a case, find the percentage of the total output this special output amounts to; then, using this percentage, find what part of the total power-house expenses of all kinds are caused by this special contract. This result is deducted from the total power-house expense, and the remainder is the power-house cost of furnishing the consumers with their share of the total output. If it is found that special employees are required to deliver this special output, their cost is deducted, and the same for the maintenance material used. Taxes and interest on the cost of this special equipment are found by ascertaining the percentage this cost of the special equipment bears to the whole plant.

The above results are deducted from the total operating, maintenance, taxes, and interest disbursements, and "Fair and Equitable Value," and the remainders are used as the cost of the last year's expenses for furnishing the consumers with their share of the product and the "Fair and Equitable Value."

The same method is used in determining the revenue paid by the consumer.

The above result, *i. e.*, cost of operating, etc., is then used as the basis for estimating the expenses for the period of the new contract, as heretofore set forth.

If the charter comes under Class II or III, the city no doubt

has incorporated a clause for the adjustment of rates, and the method used above is followed. Mr. Ledlie.

15th.—Where the franchise has expired and is going to be renewed, the same method holds.

16th.—Where the franchise has expired and the city has paid a certain amount for service, and is to buy the property, the same method is used, except in determining the intangible value. For determining the latter, the amount the city pays for service is deducted from the gross collected revenue. From expenses is deducted the same percentage as the amount of the city's payment is of the gross revenue; a net revenue is found from this, the taxes paid are deducted, the remainder is capitalized as heretofore set forth, and is the intangible value. Whatever the latter amounts to is added to (or deducted from, in case of deficit) the "Fair and Equitable Physical Value," and the result is the price the city should pay.

Cities generally claim, and so do their "experts," that they should only pay junk value, or the cost of a modern plant to give the same results. This is eminently unfair, because the city buys a property which is in full operation and it receives the full revenue, in addition to obtaining service for itself at a less cost than it heretofore paid. The difference between the cost to the city of furnishing the service itself, and what it paid the company, is profit, but there is a charge against this of loss in taxes. These two latter items, namely, profit and taxes, generally balance each other, although the writer has known of cases where the city was the gainer.

There are many points which can be advanced to establish the fairness of the methods outlined herein, but they would take some time to explain, and therefore the writer has only set out the plan he follows in his examinations, hoping that it may be of some aid in establishing a uniform method which will be upheld by the Courts.

It may be stated that recently this method was used in an examination, going back thirty-five years, and the results were accepted by both sides without question.

The writer has refused a number of examinations when told in advance what result must be found, as well as in "expert" work, where the examiner is expected to help make a case, regardless of his honest judgment, for, by accepting such work, he hurts his reputation and lays the Profession open to such remarks as Judge Lacombe recently made in the case of the Peoria Water-Works Company *vs.* Central Railway Company.

The writer is fast coming to the conclusion that a great deal of legal trouble is caused by the decisions of commissions, the members of which have not had experience in these matters. If a commission consisted of an able lawyer, a financial man, and an engineer who has had a broad operating experience, its decisions would carry weight, and the Courts would not be burdened with so many appeals.

Mr. Raymond.

WILLIAM G. RAYMOND, M. AM. SOC. C. E. (by letter).—This is, perhaps, the best paper on the valuation of public service property that has yet appeared. The author's analysis is very clear, and his arguments are convincing. Three points the writer would like to consider; two of them briefly.

The item, "going value," even if it is determined on logical reasoning, as suggested by Professor Mead, would seem to be a dangerous item, and one which might result in absurdities when estimated by an unscrupulous, ignorant person. Moreover, the term has been differently defined, and there is no certainty as to just what it means. The writer sees no reason for the existence of such a term, or of such a separate quantity as this term is supposed to represent.

The term, "franchise value," or, "value of the franchise," is used to represent the difference between the capitalized net earnings and the value of the physical property. Of course, there is such a difference, either positive or negative, but there seems to be some objection by the Courts to calling this "franchise value." The writer, therefore, would suggest that, since franchise value is a very elusive item, depending on the life of the franchise, the attitude of the community toward the corporation, the activity of competing corporations, and numerous indeterminate items, the term, "business value," or, "going concern value," be used instead of "franchise value." "Going concern value" is not as good a term as "business value" or "value of the business," because it may be assumed to include both the value of the business and the value of the property. "Value of the business" would presumably include the value of the franchise, and perhaps would not always be represented exactly by the difference between the capitalized net earnings and the value of the physical property, but would be this difference affected by some judgment percentage resulting from a consideration of the probable continuance of the franchise.

Mr. Riggs has truly said that the value of the physical property must not be made to depend on the purpose for which the valuation is made; that, for the business for which it is used, the value of the physical property is the same, regardless of the purpose for which a valuation is desired; but valuations are made for different purposes, and, while there is room for argument as to the proper valuation to be used for capitalization, taxation, or sale, there are perfectly definite methods suggested for valuing property for these purposes. The writer has never seen a statement—that appealed to him as at all rational—of a proper method of valuing property for rate-making. Indeed, the writer has said* that "proper traffic rates have no relation to valuation except that the minimum net income should be at least sufficient to pay interest on the physical valuation." The writer is not absolutely certain of the correctness of this position, for a study

*"Elements of Railroad Engineering."

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of the public right to regulate a corporation which is performing a semi-public function seems to indicate that the public has a right to say, not only that rates shall be non-discriminatory, but also that they shall be reasonable.

Now, the writer is familiar with three bases for the determination of what constitutes reasonableness of rates. One, which applies to rates as a whole, is this: That the net income should produce not more than a reasonable interest rate on the actually invested capital. Another is the rate that the traffic will bear, and the third is a rate that represents what the service is worth to the purchaser. Of course, a difficulty arises in determining reasonable rates on any one of these three bases.

The only difficulty with the first one is in determining what is a reasonable interest rate on invested capital, and, as far as the writer has read, no Court has yet determined what this is, although some Courts have held that 5% is a not unreasonable return, that 8% is a not unreasonable return, and, if the writer's memory serves him right, that even 15% is a not unreasonable return.

There is great difficulty in the determination of what the traffic will bear. It is a matter of the exercise of judgment and of experiment, and must be applied to a considerable extent to particular rates, for particular commodities, for particular places.

The third basis would seem to be the most difficult to use, although it is one which has recently been established in important Court decisions, and is mentioned by Mr. Riggs. What is a monopoly-provided service worth to the user or purchaser? Suppose that a gas company charges $1.60 per 1 000 cu. ft. for gas, and a very considerable part of the populace living in the city served purchases gas at this price. Presumably the purchasers pay what the service is worth to them, and what they are willing to pay rather than suffer the inconvenience of tallow candles, oil lamps, or to pay a high price for electric lights. Suppose that through a period of five years, by a series of reductions voluntarily made, the price of gas finally reaches $1.15 per 1 000 cu. ft. Is this gas worth any less to the consumer at the end of the five-year period than it was at the beginning? So far as the writer can see, it is, for only one reason, namely, that it can be had for less; but this has been a voluntary reduction on the part of the supply corporation, and who shall say that the service is not worth less than $1.15 to the consumer, or who shall say that it was not worth less than $1.60 at the beginning of the period suggested? The figures here given represent an actual case which has occurred during the last five years, within the writer's knowledge. There seems to be a growing feeling among the people that rates as a whole must be fixed so as to yield only a reasonable return to the corporation, and, apparently only for want of the suggestion of a better method, a reason-

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able return has been held to mean a reasonable return on the capital invested. Believing that there may be some ground for the claim that rates as a whole should be thus fixed, and that the return should not be unreasonable, let us consider how what is reasonable may be determined.

In the first place, it appeals to the writer that the invested capital is not the proper basis for estimating reasonable rates. If it shall be finally established that a corporation is entitled to realize only a reasonable interest rate on the capital invested, there will be no more public service corporations organized; but, if the reasonableness of the return may be based on the capital invested and the business done, there will still be good inducement to capable men to engage in public service business.

It would seem that the rate of return that is reasonable differs for the capital invested and for the business done—that is to say, if the capital invested is $1 000 000, an ordinary investment return of from 4 to 5% may be sufficient; and if the business done with this million-dollar plant amounts to $10 000 000 a year, a reasonable return may be 10% or even 15% of the whole.

Now, as has been suggested by Mr. Riggs, it is manifestly impossible to capitalize the net earnings as a basis for determining reasonable rates, because these net earnings are the result of certain rates already established, the reasonableness of which may be in question; and if, instead of speaking separately of interest rate on capital actually invested and profit rate on business done, it is desired to obtain a value on which to base reasonable rates, the following is suggested as a method: Determine the physical value and the annual interest on this physical value at an assumed reasonable rate, say 5%; determine the annual expense of conducting the business, and assume a business man's profit rate, say 15%, and find the profit that should be earned on the business done. This, added to the total interest charge, should give the net income, over and above operating expenses, that may be considered reasonable, and this sum, capitalized at any given assumed reasonable interest rate, would give a value which might with reason be used as a basis for rate-making, rates being deemed to be reasonable as a whole which furnish from year to year a simple reasonable interest rate on this established value. Of course, there is no necessity for establishing such a value, as the reasonableness of the rates will be determined when it is learned that they produce not more than a fair interest rate on the actual physical value of the property plus a fair profit rate on the business done.

This method is not free from the objection that what is a reasonable interest rate and what is a reasonable profit rate have never yet been fixed, but it is much easier to fix these separately than to fix what is a reasonable return on the capital actually invested or the physical valuation of the property.

Mr. Williams.

W. H. WILLIAMS, ESQ. (by letter).—Before entering upon the discussion of the more essential elements of the problem presented by this paper, it seems worth while to correct one or two misapprehensions under which Mr. Riggs seems to labor, and to call attention to the rather extraordinary temper in which he approaches the grave questions with which he deals.

Mr. Riggs' first serious misapprehension is that railway officers, as a class, are, with substantial unanimity, opposed to any official valuation of railway properties, and that this opposition was voiced through the writer's discussion of Professor Henry C. Adams' paper in favor of valuation, at the last annual (December, 1909) meeting of the American Economic Association. Of course, on that occasion, the writer spoke, as he now speaks, only for himself, but, more than that, he then expressly disclaimed any such opposition, undertook to make suggestions as to the manner in which a proper valuation could be obtained, and directed his criticisms plainly at a proposal which contemplated, as he then observed:

"An incomplete and misleading valuation bearing the stamp and carrying the weight of governmental sanction, which can be of no practical advantage to the Government, the public, or the railways; but may easily injure the public and the railways by disturbing the confidence of the former and hampering the activities of the latter."

The writer then added:

"It seems very clear that such a valuation as is proposed would be wholly useless to the Government for any practical purpose, because it would omit so many factors essential to any fair appraisement of the worth of the enterprises as going concerns."

Bearing in mind that the foregoing was addressed to the particular proposal made by Professor Adams, that being the topic on which the writer was invited to speak, a proposal expressly limited to the ascertainment of cost of reproduction less depreciation (the equivalent of cost of replacement with second-hand materials in a condition equivalent to that of the materials in use and hereinafter referred to as "cost of replacement") under the pseudonym of "physical value" (or sometimes "inventory value"), it would seem as though Mr. Riggs should sympathize with the writer's view, rather than with that of Professor Adams. Certainly, Mr. Riggs is fully aware of the inadequacy of mere cost of replacement to serve any useful purpose, for, after saying that:

"No account may be taken of the purpose for which the resultant figure of value is to be used; and the result should not vary, no matter what the purpose may be."

He says, in another place:

"* * * it is clear that the worth of the physical property, being the cost of reproduction less depreciation, is not necessarily the value of the property. * * *"

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And, defining what he calls the "non-physical or intangible elements of value," says:

"These are those things which, added to or taken from the worth of the physical property, make up the value, and include whatever accrues to the property by reason of its operation, or by reason of grants, contract rights, competition, or location, which at the time of appraisal affect favorably or unfavorably the worth of the property."

The second misapprehension that is worthy of notice seems to have grown out of a curious sensitiveness, on the part of Mr. Riggs, as to any suggestion, other than his own, of criticism of any work undertaken or theories advanced by Professor Adams. As to every reader, other than Mr. Riggs, it is surely quite unnecessary to say that no attack has been made upon Professor Adams by the writer at the New York meeting of the American Economic Association or anywhere else. Certainly, it will be conceded that some difficulty would attend an effort to respond to an invitation to discuss before a scientific body a paper written by one of its members without making any allusion to the author of the paper or to his views or work, and those who have any knowledge of the history of official railway valuations in the United States, and especially of the proposal to undertake a Federal investigation of cost of replacement, are fully aware that Professor Adams has been from the beginning, and now is, the Hamlet of the drama, without whom it would become dull and lifeless. Strangely enough, Mr. Riggs seems to wish to deny to Professor Adams this prominence, for he says:

"Professor Adams was associated with the Michigan appraisal, but had no connection whatever with the 'physical valuation,' to which such objection is taken, and his appointment was made after the work of physical valuation had been fully outlined and was well under way."

It is true that the scheme devised by Professor Adams, and adopted at his suggestion by Governor Pingree, required the employment of civil engineers for the preliminary work which necessarily had to precede the final "valuation" by Professor Adams, but the bare statement of this fact is utterly misleading. Professor Adams' own testimony in one of the Michigan tax cases happily places his responsibility for the whole plan entirely beyond controversy. He said:

"In 1900 I was called upon by the Michigan State Tax Commission to determine whether railroads were paying a tax rate on their value equal to the rate on other property. With that problem in view, I formulated this inventory plan. * * *"*

Any discussion of the proposal for a National inquiry concerning cost of replacement which omits to show that its most persistent advocate, Professor Adams, has advocated and actually conducted or

* Michigan Central *vs.* Powers Record, p. 500.

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controlled several successive "valuations," in Michigan, as Statistician to the Interstate Commerce Commission, and as special employee of the Bureau of the Census, made in accordance with other methods than those which he now proposes to apply, is seriously inadequate; as seriously inadequate as it would be to omit to state that, using what purported to be the same method, Professor Adams, by changing the details of its application and decreasing the rates of interest used in his computations, raised his "valuation" of Michigan railways from $152 958 202 to $177 689 292 or 16.17%, each of the two calculations being presented to the public, with assurances that it disclosed the actual taxable value, and there being barely eighteen months between them. The writer is by no means alone as an object of Mr. Riggs' dissatisfaction because of public criticisms of Professor Adams' plan for estimating cost of replacement. Thus, of a statement in which Professor Taylor, who conducted the Wisconsin inquiry, questioned the validity of some of Professor Adams' methods, he writes:

"Undoubtedly this statement was made in good faith, and has gained currency by not having been corrected, but it is not the fact."

In another place, referring to a statement of comparative costs to the respective States for valuation work, made by the Railroad Commission of the State of Washington, he says:

"It does not appear to be good taste either to criticize costs of work in other States, or compare the costs in Wisconsin and Michigan with the cost in Washington."

Referring to a paper by Charles Hansel, M. Am. Soc. C. E., who took part in the Michigan valuation, Mr. Riggs says:

"The one point to which special attention is drawn is Mr. Hansel's astonishing misconception of Professor Adams' plan of work. This misleading statement appears in the first paper and is reiterated in the second."

Again, of the report of the expert of the Washington Railroad Commission, who had the temerity to declare that it found "little value" either in Professor Adams' methods or his estimates of the cost of the work, Mr. Riggs says:

"Such sentences, and others which, by inference if not by name, reflect on work executed by men of high professional standing, are hardly in good taste, even if true, in a report to a railroad commission of another State."

Yet Mr. Riggs does not fail to criticize the method of "valuation," applied by Professor Adams in Michigan, in terms quite as definite as any used by others.

Thus, he condemns the method used to estimate the value of the non-physical elements appertaining to the Michigan railways, on the grounds (first) that it made this value a mere derivative of the rates

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existing, and (second) that it made no allowance for negative values when cost of replacement exceeded real value, saying:

"It will be seen that, in the case of a property in which the surplus earnings depend on excessive rates for service, it will fail as a method of determining a value for use as a basis of rate-making; and it fails, in the form in which it was used in 1900 and 1902, to bring out those negative or subtractive elements which may be determined from the income accounts, in the case of properties which do not earn a fair return on the investment."

Of the published statistics of American railways, compiled in the office of which Professor Adams is the responsible head, derived from annual reports made in accordance with forms prescribed by the Interstate Commerce Commission under his guidance, and containing items selected from and depending on the uniform railway accounting system devised by Professor Adams and imposed on the carriers by the Commission, Mr. Riggs writes:

"The published statistics are in such form that only the careful student of affairs can understand or analyze them, and but few of the public officials who receive them are able to read the reports of the properties and comprehend them."

Railway officers fall quite generally under Mr. Riggs' condemnation, for, of them he says:

"As a body * * * it is doubtful if any equal number of men, of equal intelligence, have as limited a knowledge of the fundamental truths of government, or knowledge so colored by bias. It is also doubtful whether any equal number of men have in their ranks so few who bear an active part in the duties and activities of citizenship, or who exercise large influence on their neighbors."

Such assertions as the foregoing need no comment; their intemperance is their most effective refutation; yet a few recent examples may be cited: Paul Morton resigned as Vice-President of the Atchison, Topeka and Santa Fé to become Secretary of the Navy in Mr. Roosevelt's cabinet; Jacob M. Dickinson, General Solicitor of the Illinois Central, became Mr. Taft's Secretary of War; his successor with the Illinois Central, William S. Kenyon, later became Special Assistant of the Attorney-General; Lloyd W. Bowers, General Solicitor of the Chicago and Northwestern, was Solicitor-General of the United States from early in Mr. Taft's administration until his death a few months ago. Thus, within but four or five years, the Federal Government took four of its highest officers from the railway officers located in only one of the country's great cities—Chicago.

Of a recent address by one of the ablest and most public-spirited of railway officers, he says:

"This address well expresses the spirit of the railway managers and employees toward all forms of investigation, and the complete lack of

understanding, on the part of these managers, of the legal and moral relations which they bear to the communities which they serve." Mr. Williams.

Belonging to this so hateful class, and having also ventured to question whether Professor Adams has said the last and most perfect word on the subject of railway valuation, the writer is neither surprised nor disheartened to find that he, also, has caused Mr. Riggs undisguised dissatisfaction. It is a misfortune apparently inseparable from his profession and his conception of his obligations to his employers and to the public.

As has been already noted herein, the question is not whether railway property shall be officially "valued," but rather (first) as to how the "value" which is to be ascertained is properly to be defined, and (second) how the determination of "value," as properly defined, can be made most accurate.

The essential difference between the view advocated before the American Economic Association by Professor Adams and that of the writer was, and is, that the former now desires to exclude all elements of value which are not physical and tangible, while the writer holds that, if it is worth while to ascertain, on a general scale, at the cost of a necessarily large expenditure of taxpayers' money, and as to a particular date, so unstable a fact as railway value, the kind of value the ascertainment of which could be of sufficient utility to warrant the effort can be nothing less significant than the "fair value" which the Courts have said is a proper element for consideration in fixing reasonable rates of charge. The fundamental difference between these two conceptions of value is admirably indicated by the following quotations, both of which rest on the authority of the Interstate Commerce Commission.

FAIR VALUE.

"The present value of a railroad property is necessarily very largely a matter of opinion only; it depends upon a vast number of contingencies and uncertainties, a road apparently of great value to-day may soon become worthless by the opening of a competing line having superior advantages or by the competitive struggles of other lines which operate to reduce the income of all; the value of a railroad largely results from the personal characteristics of its officials; the policy pursued by directors for the conservative and economical

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"The bill in question makes use of the phrase 'fair value.' Unless there is some legislative necessity, which we do not perceive, we question the advisability of using this phrase.

"It would seem to us preferable to substitute a phrase which indicates the fact that Congress desires an inventory valuation of railway property. By inventory valuation is meant that the property of the several railways shall be listed in detail, and that each kind or class of property so listed shall have assigned to it a valuation to be determined from the

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or progressive and daring, is a great factor in the determination of the current value of the property; a railroad property is not necessarily worth what it would cost to replace it and, on the other hand, it may be worth very much more than that."

Second Annual (1888) Report of the Interstate Commerce Commission, p. 64.

point of view of the contracting engineer, and not from the point of view of a court or board of arbitration which, from the nature of the case, cannot judge of what is 'fair value' except in the light of some specific use to be made of the valuation."

Letter of Hon. Martin A. Knapp, Chairman of the Interstate Commerce Commission, to Hon. Stephen B. Elkins, Chairman of the Senate Committee on Interstate Commerce, covering a then pending bill providing for railway valuation, March 25th, 1908.

As has already been noted herein, and amply verified by quotations, Mr. Riggs is fully aware that replacement cost and real value can rarely, if ever, coincide, and therefore plainly agrees, as to that elementary and essential point, with the writer and disagrees with Professor Adams, who would ignore or destroy every non-physical element of value in the property of all public service corporations. Mr. Riggs' recognition of the inadequacy of mere replacement cost is shown also by the excellent and convincing example which he cites* of competitive railway routes between two Michigan cities which were built and are maintained and operated under such conditions that the far more costly of the two, which inferentially has correspondingly higher replacement cost, has much lower earning capacity, both as to gross and net, and is therefore actually worth much less than its less costly competitor. Mr. Riggs explicitly favors full recognition of the non-physical elements in every valuation; and, therefore, may be ranked as an opponent of any such scheme of valuation as that advocated by Professor Adams before the American Economic Association, or in the letter of the Chairman of the Interstate Commerce Commission, hereinbefore quoted.

Mr. Riggs, however, believes that the determination of the cost of replacement is an essential first step toward the ascertainment of real value. He says:

"The worth of the physical property is primarily that on which the value of the whole property rests."

The thought which the writer would place in opposition to the foregoing is that: Physical property has no value which is not an expression of its adaptation to economic needs. This is only another way of expressing the inevitable economic law, from which there is no escape, either in theory or in practice, that has been stated and sanctioned by the Supreme Court of the United States, as follows:

"But the value of property results from the use to which it is put, and varies with the profitableness of that use, present and prospective,

* Pages 18-19.

actual and anticipated. There is no pecuniary value outside of that which results from such use."* Mr. Williams.

Mr. Riggs' own definition of value is not inconsistent with the foregoing. He says:

"The value of a property is its estimated worth at a given time, measured in money, taking into account all the elements which add to its usefulness or desirability as a business or profit-earning proposition."

The view of Mr. Riggs is that:

"While * * * the worth of the physical property, being the cost of reproduction less depreciation, is not necessarily the value of the property, * * * the physical worth must bear some very definite relation to value. * * *"

And he is, further:

"Strongly of the conviction that this relation is such that 'value' cannot be ascertained without a determination of physical worth."

It is exceedingly difficult to comprehend just what Mr. Riggs means when he describes the relation between real value (which he recognizes so clearly as value in use) and cost of replacement as "very definite." Certainly, he does not mean that it is a constant relation, or one which can be ascertained until there has been independent determination of both of the aggregates whose relation it expresses. In fact, the emphasis which Mr. Riggs places on replacement cost has led him into the grotesque fallacy of arguing that a correct estimate of real value is only to be attained by ascertaining: (first) cost of replacement, (second) real value, and (third) correcting the aggregate first obtained by applying whatever "very definite" relation (ratio) is necessary to make it agree with the second aggregate, which was from the beginning the only aggregate really wanted. The accuracy of this characterization of his proposed procedure is made perfectly clear by the following quotation:

"* * * the true method of valuing a corporate property is first to determine the cost of reproduction of the property and its depreciation, and modify this figure by any applicable positive or negative non-physical elements of value."

It is submitted that the clear meaning of the foregoing is that both replacement cost and real value as derived from use must be separately and independently ascertained, and that, these aggregates having been compared, the former is to be corrected by whatever allowance for non-physical value may be required to make it agree precisely with the latter. The obvious suggestion flowing from this discovery of his theory is that only value in use is wanted, as that is the only real value, and as it must be separately ascertained in any

* C., C., C. & St. L. Ry. *vs.* Backus, 154 U. S., 445.

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event, no other and *pseudo* value need be taken. The essential character of the method is as described, even when it is applied through determination of the annual value of the use and the assignment of one portion of such annual value to return on the capital value of the physical property and another portion to return on the capital value of non-physical property. The real nature of the method is not even effectually concealed by the capitalization of the income assigned to physical property at one rate and the income assigned to non-physical property at a different and higher rate. In fact, if it is necessary to conclude that a portion of the net annual income of railway property is normally paid to, or in respect of, a portion of capital entitled to a lower rate of return, and the remainder to or in respect of a remainder of capital entitled to a higher rate, the appraisal of the physical property is an excessively costly, cumbersome, and inaccurate expedient for determining the amount or value of either portion of the capital. Yet that is exactly what was done in Michigan by Professor Adams, the "valuation" he then made being completed before he altered his view by deciding that the non-physical elements of value are entitled to no consideration whatever, and that only cost of replacement is worthy of inclusion in an official "valuation."

But is there any real distinction between the "physical properties" and the "immaterial elements," such as the foregoing extract seems to assume? Is not the superficial appearance of such a distinction plausible but deceptive? A locomotive is an entity; so is a railway. The separate parts of a locomotive are most of them independently valuable; so are the separate parts of a railway; but a large share of the value of the locomotive is the result of the nice adjustment of these separate parts to each other and to the work to be done.

Take a hundred different-sized locomotives, each adapted to different work under different conditions, and separate each piece of metal; it would be possible to value all these parts, but the aggregate would be far less than the value of the locomotives from which they were taken. Again, it would be possible to construct from these parts a hundred locomotives of such poor design, their respective parts so out of adjustment and balance, that they would be worth even less than the parts out of which they were assembled. The highest paid intelligence has not yet contrived the perfectly balanced locomotive, but a large part of the so-called "physical value" of every locomotive represents this sort of highly paid intelligence put forth at every stage from the opening of the mine where the ore was obtained to the delivery of the completed locomotive. Take ten railways of a thousand miles each, every one of them efficiently constructed, and equipped with proper terminals, stations, signals, rolling stock, and trained employees, and each properly adapted to the requirements of its territory and traffic; separate them into piles of ties and rails, groups of locomotives and cars,

acres of land, unorganized bodies of men of varied capacity and training; what sort of intelligence will it require to build up out of these masses ten railways as efficient and useful as those that originally existed? Why, then, should the "physical value" of the locomotive include the assembling of its parts in proper balance and the "physical value" of the railway exclude the cost of the much more complicated adjustment of its elements of machinery and labor and location to each other? Mr. Williams.

At an early point in his discussion, Mr. Riggs makes an announcement, highly becoming on the part of one who proposes to deal with the problem solely from the point of view of a civil engineer, that he does not intend to argue the public utility of any sort of valuation, but only the method by which it may best be made, should one be determined upon. He says:

"This paper is confined to a discussion of the methods which should be used in arriving at a correct figure of cost of reproduction and depreciation—it does not take up questions involving the propriety of those figures when reached. The propriety or legality of using such figures as a basis for an assessed valuation, as a basis for rate-making (rate-making being an art in itself involving complications as great as those encountered in valuation), or any arguments as to the justice or injustice of legislation restricting issues of stocks or bonds, will be conceded no place in this paper. It is assumed that all these questions would have been taken up and a satisfactory answer reached before a valuation could have been ordered."

Two pages after the foregoing paragraph, under the sub-heading "The Relation of Public Service, or Quasi-Public Corporations, to the People," Mr. Riggs proceeds to violate the wise, though self-imposed restriction, and devotes no less than eleven pages to a defense of the project on grounds of alleged public policy. In these pages he concludes that such a valuation as he proposes—not a mere determination of replacement costs, but a real valuation, with proper allowance for all elements of value in use—would be of service in connection with (*a*) taxation, (*b*) public control of rates, and (*c*) public control of issues of capital securities.

In supporting valuation as an expedient in taxation of railway property, Mr. Riggs seems to rely on a table made up from Professor Adams' Bulletin No. 21, as expert employed by the Federal Bureau of the Census, which table shows that the assessment of the railways of Wyoming for taxation purposes in 1904 was but 7.5% of their commercial valuation, as estimated by Professor Adams, and that this ratio varied greatly throughout the different States, running as high as 114.4 in Connecticut. Of course, nearly every one knows, even if Mr. Riggs does not, that the relation between the real value and the assessed value of all other kinds of property varies greatly from State to State, and even in different portions of the same State. On account

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of this variation, no table such as that offered by Mr. Riggs in support of his argument can have any value unless supplemented and explained by data covering the assessment of other kinds of property. It is worth noting, *en passant,* that the so-called "Commercial Valuation," on which Mr. Riggs rests this part of his argument, assigns a value equivalent to $32 054 per mile to the railways of Michigan and one of $45 211 per mile to the railways of the prairie State of Nebraska. Possibly this variation in the estimate of value is partly expressed in the conclusion that Michigan railways are assessed at 70.9% of their value and Nebraska railways at but 18.5 per cent. Obviously, there is no more need of uniformity among the States in the taxation of railway property than in their methods of deriving revenue from other kinds of property.

Also, Mr. Riggs admits that, when the Michigan valuation for taxation was made, it was not diminished, as it should have been, by the use of negative, non-physical value. This is fully equivalent to an admission that the method was unjust to every railway not capable of earning the full return on its replacement cost. He says:

"The use of a negative or subtractive non-physical value was considered, and advised by Professor Adams. * * *

"Professor Adams and his associates, therefore, applied only positive values, where any such were found, although advocating the use of negative values."

And, of the method then used, he says:

"* * * it fails, in the form in which it was used in 1900 and 1902, to bring out those negative or subtractive elements which may be determined from the income accounts, in the case of properties which do not earn a fair return on the investment."

And again:

"* * * where the earnings have been fairly uniform and stationary for a period of years, and the property does not earn a sufficient sum to care for depreciation and annuity, it is clear that the value as an earning investment is less than the determined physical value, and that the physical valuation should be reduced by some amount to arrive at the 'fair value.'"

In his argument favoring the use of a valuation in rate-making, Mr. Riggs affords no support to Professor Adams' contention that, for that purpose, only replacement cost should be considered, and that, after fixing the rates on the basis of the least favorably located and least efficient line, so as to afford it a bare return on its replacement cost, the surplus earnings at the same rates of its more favorably located or better operated competitors should be confiscated under the guise of a special tax. This extraordinary proposal, the character of which is so illuminating as to the attitude toward railway property and investments of the most prominent and persistent advocate of

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so-called "physical valuation," is best stated in Professor Adams' own words, which are as follows:

"I cannot evade the conclusion that equity, as between various classes of roads, can never be attained until all the excess of revenue over the Constitutional limit be made a contribution to the public treasury, and that this contribution be made as a substitute for all taxes of all kinds and all sorts."*

On the contrary, Mr. Riggs distinctly upholds the right to earnings in excess of the bare return, at the minimum rate of interest, upon the cost of replacement, saying, *inter alia:*

"It is contended that the determination of rates that will be just and fair to all competing companies involves other consideration than the valuation of either physical or intangible properties, and that when all these rate-making problems are properly solved, there will remain large intangible values on the well-designed plants."

Professor Adams has himself admitted that there is no possibility of utilizing any valuation for the purpose of fixing specific rates, as such a task is far beyond the capacity of any conceivable system of cost accounting. Supplementing this admission, Mr. Riggs' opposition to the plan proposed by the former and its gross injustice, so apparent to every one but its author, destroys the last element of plausibility in the suggestion that any sort of valuation could be of utility in that connection. The writer is not overlooking the fact that the Courts, when under the necessity of repelling efforts to confiscate railway properties under the guise of rate regulation, and in view of the form in which this necessity has commonly presented itself, have accepted "fair value" as an element of importance in their inquiries; but if the railways are entitled to charge rates based on the value of the services they perform, it is clear that the question whether a rate or a schedule of rates is reasonably adjusted to the value of the service or services is very different from the question whether a fair return upon fair value has been allowed. Assuming, however, the need of an appraisement in every litigated case involving railway schedules, it is evident that each case would have to have its own appraisement, for value is ever changing and unstable. Mr. Riggs himself says:

"It is true that the 'value' of a property is an unstable figure, subject to fluctuations due to natural or artificial causes, and that a material change in value may occur suddenly, * * *"

Professor Adams proposed to keep his replacement cost up to date by annual accretions equal to annual expenditures for extensions and betterments; but this plan is illogical and inconsistent, for it proposes to ignore that very essential difference between original cost (less a proportionate allowance for wear and tear) and present worth, which

* *Proceedings* of the 22d Annual Meeting of the American Economic Association.

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is the very basis of the argument in favor of any valuation at all. Equally obvious objections, growing out of the instability of the ascertained value of any particular date, apply to any plan which does not provide for a re-appraisement every time the aggregate is to be used.

The objections to the use of any valuation for rate-making which have been cited are valid, and should be convincing, but they are insignificant by the side of the fundamental objection that, as Mr. Riggs says, "as a business proposition, the value of any property depends on its earnings," while those who would thus utilize a valuation are attempting to reverse the fact and make earnings depend on the value. Such a reversal is impossible. Ascertain real value and you have a consequence of earnings, past, present, and prospective, nothing else; use this as a basis for a rate schedule and you get, as a mathematical result, the present rates. The only way to derive any other result from this method would be to use as the basis some figure other than the real value, a method which would only be resorted to through moral turpitude or intellectual incapacity. One might almost assume that Mr. Riggs knows this, for he says:

"Value is given to a property, either by reason of the fact that it is an instrument for earning profit, or that it does earn profit or gives promise of profit."

The substance of Mr. Riggs' argument on capitalization control is that American railways are not often over-capitalized, but such evils do obtain in other industries, and therefore railway issues of capital securities ought to be restricted.* Unfortunately, he gives no clue to the methods he would have applied, nor as to how far he would go in interference with the normal action and interaction of commercial forces in determining what securities can and ought to be issued. Railways are not over-capitalized. Table 9, a comparison of official valuations and capitalization, originally compiled by Mr. Slason Thompson, is instructive.

TABLE 9.

State.	Year.	Valuation by commission or tax board.	State proportion of capitalization.
Minnesota	1907	$411 735 194	$334 979 691
South Dakota	1909	106 494 503	108 911 000
Wisconsin	1909	284 066 000	249 299 060
Texas	1909	413 000 000	412 465 743
Washington	1908	186 007 490	153 493 940
Total		$1 401 303 187	$1 259 049 434
Excess of total valuation over total capitalization			$142 253 753

*Page 14.

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In view of frequent suggestions, in the public press and elsewhere, which indicate that there is a wide-spread opinion that the securities of railways have generally been watered, Table 10 is given. It is an analysis of the consolidated balance sheet as given in the reports of the Interstate Commerce Commission for 1908 and 1890.

Table 11 shows the length, in miles, of main and other tracks in 1908 and 1890.

The Commission, in its annual report, shows the securities issued per mile of road (first main track), but does not show the results per mile of main track (*i. e.*, 1st main track, 2d, 3d, 4th, and other main tracks), nor does it show the results per mile of all tracks (*i. e.*, main tracks, yard tracks, passing tracks, and industrial tracks). From the consolidated balance sheet, it will be noted that the securities per mile of road have increased 29%, while per mile of main track they have increased only 24%, and per mile of all tracks they have increased but 14 per cent. However, deducting the investments in stocks and bonds of other corporations, and showing the results only for the securities issued on account of the cost of road and 12% equipment, we have an average per mile of road of $62 388, an increase of 12%; and an average per mile of all main tracks of $56 166, an increase of 8%; and an average per mile of all tracks of $42 864, or a decrease of 0.7 per cent. It will be noted that a considerable part of these increases is due to increased cost of equipment, and the advantageous results obtained from such investment have been clearly shown. Of the investment in the track itself (cost of road), it will be noted that the cost per mile of main track has increased only 5%, while the cost per mile of all tracks shows a slight decrease in 1908 as compared with 1890.

These comparisons are more significant and convincing in the light of the large expenditures since 1890 for the reduction of grades, revision of line, interlocking towers, automatic block signals, increased weight of rail, increased capacity of bridges, improved stations and terminals, elevation of tracks, and the many other items going to make up the additions and betterments, and increasing the book cost of the property. The figures plainly prove that there has been no general practice on the part of the railroads of the country, from 1890 to date, of issuing capital securities without securing full value for the vast amount referred to. Why, then, should any restriction be placed on the form or manner of their future appeal for the very large volume of capital necessary to keep abreast of American industrial development? Why should they be limited as to what form of security they may offer in return for the cash capital which they must obtain if they are to serve the public adequately and properly?

It ought also to be borne in mind, in this connection, that, while there could be no lawful mode for the revision of existing capitalization, should it in any instance be found to be too small or too great

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TABLE 10.—CONSOLIDATED BALANCE SHEET FOR RAILROADS OF THE UNITED STATES, EXCLUSIVE OF TERMINAL AND SWITCHING ROADS.

	ASSETS.							
	Total.		Per mile of road.		Per mile of main tracks.		Per mile of all tracks.	
	1908.	1890.	1908.	1890.	1908.	1890.	1908.	1890.
RAILROAD:								
Cost of road	$12 035 195 403	$7 333 096 430	$56 268	$51 400	$50 656	$48 109	$38 659	$40 033
Cost of equipment	1 178 571 137	422 290 951	5 510	2 960	4 961	2 770	3 786	2 305
Material and supplies	226 250 462	63 785 950	1 058	447	952	419	727	348
Total	$13 440 017 002	$7 819 173 331	$62 836	$54 807	$56 569	$51 298	$43 172	$42 686
INVESTMENTS:								
Stocks owned	$2 115 313 379	$489 049 859	$9 890	$3 428	$8 903	$3 208	$6 795	$2 670
Bonds owned	1 271 311 512	241 115 665	5 944	1 690	5 351	1 582	4 083	1 316
Total	$3 386 624 891	$730 165 524	$15 834	$5 118	$14 254	$4 790	$10 878	$3 986
CURRENT ASSETS:								
Cash and current assets	$1 213 575 272	$307 874 188	$5 674	$2 158	$5 108	$2 020	$3 898	$1 681
Sinking, insurance, and other funds	154 975 409	125 095 987	724	877	652	820	498	683
Total	$1 368 550 681	$432 970 175	$6 398	$3 035	$5 760	$2 840	$4 396	$2 364
Miscellaneous	$1 277 458 795	$710 300 536	$5 973	$4 979	$5 377	$4 660	$4 103	$3 878
Grand total—All assets	$19 472 651 369	$9 692 609 566	$91 041	$67 939	$81 960	$63 588	$62 549	$52 914
	LIABILITIES.							
SECURITIES ISSUED:								
Capital stock	$7 289 597 964	$4 179 156 990	$34 081	$29 293	$30 682	$27 417	$23 415	$22 815
Bonds	9 441 200 261	4 462 577 079	44 141	31 280	39 738	29 277	30 327	24 362
Total	$16 730 798 225	$8 641 734 069	$78 222	$60 573	$70 420	$56 694	$53 742	$47 177
CURRENT LIABILITIES:								
Accrued interest	.....	$25 341 994	——	$177	.....	$166	.....	$138
Other current liabilities	$1 151 233 255	440 513 629	$5 382	3 088	$4 845	2 890	$3 698	2 405
Total	$1 151 233 255	$465 855 623	$5 382	$3 265	$4 845	$3 056	$3 698	$2 543
Miscellaneous	$845 115 552	$394 918 201	$3 951	$2 768	$3 557	$2 591	$2 715	$2 156
Grand total—All liabilities	$18 727 147 032	$9 502 507 893	$87 556	$66 606	$78 822	$62 341	$60 155	$51 876
Profit and loss balance	*745 504 337*	*190 101 673*	*3 485*	*1 333*	*3 138*	*1 247*	*2 394*	*1 038*
	$19 472 651 369	$9 692 609 566	$91 041	$67 939	$81 960	$63 588	$62 549	$52 914

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when measured by the results of such a valuation, the future issue of securities must be controlled by the necessities of the carriers and the state of the market, and is also practically restricted by the Interstate Commerce Commission's accounting system, which declares what expenditures may and what may not be carried into the capital account. The law cannot compel any company to repudiate any existing security, and if it could it is not to be supposed that Congress would compel such an impairment of contract rights; public policy will not permit in practice restrictions that would prevent the issue of securities to meet the actual needs of the public and the carriers; the accounting system prevents issues of any other sort. Further restrictions would be cumulative and superfluous.

TABLE 11.

Track.	1908.	1890.	Increase.	Percentage of increase.
Single track	213 888.36	142 665.89	71 222.47	49.9
Second track	20 209.05	8 437.65	11 771.40	139.5
Third track	2 081.16	760.88	1 320.28	173.5
Fourth track	1 408.99	561.81	847.18	150.8
Total, all main tracks	237 587.56	152 426.23	85 161.33	55.9
Yard track and sidings	73 728.57	30 750.17	42 978.40	139.8
Total mileage operated (all tracks)	311 316.13	183 176.40	128 139.73	69.9

"The Interstate Commerce Commission in 1908 report that their Balance Sheet covers 'miles of road' aggregating 213,888.36 miles, whereas their statement of mileage represents all roads reporting to the Commission whether or not they furnished a Balance Sheet.

"To analyze the Consolidated Balance Sheet, we have revised the statement of mileage to cover same roads as are included in the General Balance Sheet. The 'miles of road,' *i. e.*, miles of first main track, are actual. The Commission's report not showing separately for each line the miles of other main tracks or yard tracks and sidings, the figures shown in the statement of mileage are *approximate*. It includes mileage of all second, third and fourth tracks. Undoubtedly, practically all of the second tracks, third tracks and fourth tracks are owned, or operated by, roads furnishing the Commission with a Balance Sheet. Mileage of Yard Tracks and Sidings is based on the proportion which the single-track mileage of roads represented in the Balance Sheet bears to the total single-track mileage of roads reporting to the Commission."

Mr. Riggs considers *seriatim* nine objections to the ordinary methods of estimating cost of replacement which were mentioned specifically by the writer, as among the most important commonly omitted items, in an address before the New York Traffic Club, delivered during January, 1909. He concedes that the writer is correct in urging that allowances for "working capital with which to carry on the business" and for "impact and adaptation" ought to be included, and were omitted in Michigan and have been usually omitted. These are two of the nine objections specifically raised. As to five others, Mr. Riggs seems to be in considerable doubt. Concerning the objection that an allowance of 3% for interest during construction is too low, he contends that it was justified in Michigan by the "assumption," that the whole work of replacement would be accomplished in

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one year, and also "that on long roads partial operation would commence as various sections of the line were completed." He admits that these assumptions "clearly would not be proper" under different conditions, but appears to hold that they were warranted as to the Michigan work.

Another of the writer's objections was the absence of an allowance for "wear and tear of materials during the period of construction." As to this, Mr. Riggs says:

"This deterioration is a necessary incident to any construction work. It has not been customary or usual to take account of it. To add to the amount capitalized on account of this item would be manifestly improper. The only way in which this could be cared for would be in an adjustment of the depreciation reserve when raised to cover that which takes place during the construction period."

Of course, the depreciation account, when there is one, is a charge to operation. Therefore, Mr. Riggs' anxiety to disagree with the writer has led him into a frame of mind in which he is prepared to find that it is "manifestly improper" to charge to capital the real cost of construction, but is quite proper to charge to operation a part of the cost of construction, even though this results in carrying into the operating account items of expense incurred long before operation began or could have begun.

Mr. Riggs thinks that the writer was incorrect in objecting that "a uniform price for earthwork was used, thus ignoring the varying character of soil and length of haul," but he admits that there was "practically no classification in the Southern Peninsula of Michigan, or, in fact, on 90% of the mileage of the State," and his defense goes no further than to assert that "the price * * * was not much out of the way when considered as a fair average for the territory."

His criticism of the objection to the use of a uniform price list for materials, and ignoring the source of supply and the cost of delivery at the point of use, is equally forced, for it admits that "no effort was made to use different unit prices as between counties," and only contends that "in a number of cases" differences in prices were made.

The absence of an allowance for interference by labor troubles, weather conditions (which he admits are "a frequent source of annoyance, delay, and sometimes of expense"), Mr. Riggs defends on the ground that it is "an expense difficult to separate and set up," and therefore ought to be covered by an allowance for contingencies. On the same ground, he could easily carry every item of cost of replacement into the contingent account.

The two remaining objections specifically raised by the writer are squarely attacked by Mr. Riggs. As to one of them, the propriety of an allowance for carrying charges up to the time of attaining a revenue basis, has been admitted by the Railroad Commission of Wisconsin,

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but it is a broader question than ought here to be discussed. The writer will only suggest, at present, that in some form or other, these charges must be on the whole and in the long run met out of net operating income, and that the cheapest way, for the user of the services supplied, is to carry them into the capital account—otherwise there must be an early amortization of this item, which cannot do otherwise than to throw a heavy burden on the early schedules of charges. The language of the Wisconsin Railroad Commission on this subject merits quotation, and is as follows:*

"But new plants are seldom paying at the start. Several years are usually required before they obtain a sufficient amount of business or earnings to cover operating expenses, including depreciation and a reasonable rate of interest upon the investment. The amount by which the earnings fail to meet these requirements may thus be regarded as deficits from the operation. These deficits constitute the cost of building up the business of the plant. They are as much a part of the cost of building up the business as loss of interest during the construction of the plant is a part of the cost of its construction. They are taken into account by those who enter upon such undertakings, and if they cannot be recovered in some way, the plant fails by that much to yield reasonable returns upon the amount that has been expended upon it and its business. Such deficits may be covered either by being regarded as a part of the investment and included in the capital upon which interest is allowed, or they may be carried until they can be written off when the earnings have so grown as to leave a surplus above a reasonable return on the investment that is large enough to permit it. When capitalized, they become a permanent charge on the consumers. When charged off from the surplus, they are gradually extinguished. (These facts alone, however, do not always furnish the best or most equitable basis for the disposal of such deficits.) Whether they should go into the capital account, or whether they should be written off, as indicated, are questions that largely depend on the circumstances in each particular case."

The other objection that is squarely opposed by Mr. Riggs is the refusal to allow for unavoidable discounts on the securities sold. Here he quotes with complete approval an unnamed writer, who contends that the impropriety of such an allowance is proven because, as between an issue of $10 000 000 in bonds (par value) at 4% and at 4½%, the 4% bonds bringing 90 and and the 4½% selling at par, there is an annual saving, in issuing the 4% of $50 000 in interest, and that, if the issue is to be for fifty years, this saving is $2 500 000, or $1 500 000 in excess of the discount. Of course, these figures are correct, but both Mr. Riggs and his unnamed authority seem strangely to have overlooked the fact that if a railway construction requires $10 000 000, it cannot be obtained by issuing $10 000 000 in par value at 90. The comparison,

* Decision and order of the Railroad Commission of Wisconsin, issued August 3d, 1909, in the case of Hill *et al. v.* Antigo Water Company, pp. 84-85.

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of course, ought to be based on the issue of enough bonds at each rate to obtain equal sums of money. As $10 000 000 in par value of bonds sold at 90 would produce $9 000 000, the following comparison is based on the issue of enough bonds at each rate payable in fifty years to secure that sum.

	Fifty-Year Bonds, 4½% sold at par.	4% sold at 90.
Amount of capital required....	$9 000 000	$9 000 000
Par value of bonds necessary...	9 000 000	10 000 000
Annual interest charge.....	405 000	400 000
If 4% bonds are used:		
Annual saving in interest.....		$5 000
Fifty years saving in interest.....		250 000
Loss, original discount.....		1 000 000
Net loss.....		$750 000

Of course, the foregoing figures are not absolutely accurate, for the real net loss in the issue of the 4% rather than the 4½% bonds at these prices would be the difference between the $5 000 annual saving in interest and the amounts which would have to be set aside annually for fifty years to produce $1 000 000, the amount of the discount, at the end of that period. But the table is sufficiently accurate to expose the curious error into which Mr. Riggs has fallen. Perhaps it will convince him that it would be better, hereafter, not to stray so far outside the field of civil engineering.

Mr. Riggs has little sympathy with those railway men who venture to express the opinion that regulation ought not to extend so far as to render it impossible to conduct the railway business in a business-like way. His animadversions on railway men in general have already been illustrated herein. He finds nothing worse with which to characterize a previous utterance of the writer's than to say of it:

"The manifest impatience with all forms of governmental interference with corporations, which so often characterizes the utterances of prominent railway officials, appears in this paper to a marked degree."

At the risk of incurring further displeasure, the writer will not omit now to observe that, in his judgment, the whole question whether railways shall be generally and officially valued, and how and by whom the task shall be performed, is primarily conditioned by the country's need of managing its legislative control of railway methods so as not to restrict unduly the flow of capital into that industry. The steady pressure for legislation during the last five years has so extended legislative regulation that, for the first time, the sturdy, frugal, conservative, "small investor" stands in the forefront of the problem. His

views of the stability and future prosperity of the American railway industry now dominate the situation. What they are may be read in the facts attending recent efforts to finance necessary improvements of old and prosperous railways. It developed before the Interstate Commerce Commission during the recent hearings in connection with the proposed partial adjustment of rates to the diminished purchasing power of the money in which they are paid, that one of the greatest of Eastern railway systems, paying 8% annual dividends on its stock, which is very widely distributed, had offered new shares to its stockholders at a premium of 25%, and had found them unsalable at that figure, so that it was obliged to recall the offer and put them out at par. Other testimony disclosed the failure of one great company to obtain an offer of more than 85 for its 4% bonds, while another had been forced to go to France to raise $10 000 000, and many others have been forced to the expedient of issuing short-term notes at relatively high rates of interest. It also appeared that extensive proposals for new branch lines had been abandoned or postponed, in view of the impossibility of obtaining funds on reasonable terms. Mr. Williams.

Other testimony shows that locomotive shops and car builders are putting out not more than half of their capacity; that the supply trade is receiving no new orders. Never, since the beginnings of the American railway industry, has the American and foreign investor been so reluctant to supply necessary capital, or so doubtful of the future of railway enterprises. This fact is not due to absence of confidence in the industrial future of the American people, but is directly attributable to the unanswered inquiry as to how far the policy of legislative control is to extend. Either this question must be answered in a manner satisfactory to the investor, or the credit of the Government must be made available for the extension and improvement of railway facilities, either through Governmental guaranties of adequate returns to capital, or through Government ownership; for adequate and properly constructed and equipped railways the public must and will have. Thus far, the American public is ready neither for Federal guaranties nor for Federal ownership; it is to be hoped that it will never be ready for either. In this situation, if a Federal valuation is to be undertaken, it is primarily important that it should be under such auspices and by such methods that the investor will not be alarmed as to its consequences. This is not a suitable occasion to attempt to lay down all the considerations applicable to such a valuation, but it ought to be perfectly clear that it must relate to value in use, not to some concept of value limited to replacement cost which excludes some of the most important elements of value (which are also those most worthy of a return, because they represent the highest and most difficult social and industrial services), in order to obtain a means of excluding these same elements from possibilities of adequate reward.

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One of the most important items to be considered is the "cost of progress," which is sometimes referred to as "abandoned property," or as "obsolesence." For illustration, in the revision of the grade and line of a road, whereby the capacity of existing track is doubled, the present instructions of the Interstate Commerce Commission require the charge to operating expenses of the cost of that portion of the old line no longer continued in use. If, however, the doubling of the capacity of the line be secured by the construction of a second main track, the entire cost of the new work can be charged to capital account and paid for from the proceeds of the sale of capital securities. The latter method becomes the easier to finance, but what of the comparative results? Say, for example, the original cost of material of existing property, including equipment, stations, yards, etc., was $10 000 000, that the first main track cost $1 000 000, and that to double the capacity of the main track would require a present expenditure of $1 000 000, either for (1) a reduction of the grades and curves of the first main track, or (2) for the construction of a second main track. The increase in capacity is identical, but in the first case the cost of train service to handle the tonnage is decreased 50%, and some reduction in maintenance is secured, while in the second case no economies of operation are effected, but the expenses may be increased. Undoubtedly, Road (1) would be much more favorable than Road (2), yet the Commission says a portion of the cost of perfecting Road (1) must be charged to operating expenses, and cannot be capitalized. What general manager will dare recommend such extensive improvements when the charging of a portion of the cost to operating expenses will show the dividend as unearned, and thus render the securities of the company no longer legal investments for savings banks, trustees of trust funds, etc.? As an alternative, he might permit the old line to remain, and by placing thereon a few cars occasionally, could consider it as still in use, and carry it in his capital account, thus avoiding the charge to operating expenses. Thus, again, is it the method and not the result that is controlled by these instructions. What should be done is to permit the cost to be charged against the surplus accumulated during the years in which the property to be abandoned was used. This would not affect adversely the operating income of the year, and would not impair the credit of the Company.

Plainly, the instructions of the Commission tend to compel a method that is contrary to the economic law.

Obviously, any requirement as to valuation which would impose on the carrier such a result as that shown would compel the continuance of the less efficient service and prevent the progress which such replacements express. The railway business is a continuing one, and an improvement ought to be made whenever it can earn income, not only on its own cost, but on that of the property abandoned, even

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though it cannot afford income sufficient to wipe out the whole capital charge for the latter in a single year. There is no reason for requiring each item of capital to earn its cost in addition to its interest during its individual life. Such a requirement would cry halt to progress. It is reasonable and proper that such charges to operation should be made as far as the rapid development of the art of transportation permits, and such is the practice of every well-managed railway; but, to make the practice uniform and compulsory, permitting no exceptions and allowing no scope for individual judgment, is quite another thing. When the conditions warrant such a course, the railway ought to be permitted to adjust its accounts in a manner of which the following is typical:

	Replacing.	Not replacing.
Capital account.....	$19 750	$5 000
Additional net operating income attributable to this item.....	1 000	250
Charge to operation for abandoned property	250	....
Operating gain.....	$750	$250

A valuation adjusted in recognition of this developmental need would include, in addition to the item of $15 000 for the replacement cost of the new locomotive, an item representing "cost of progress" of $4 750 for the former locomotive. It is not to be overlooked that in actual practice it would be easy to obtain this allowance by cumbering the yards and round-houses with obsolete and superfluous equipment. The plan of Professor Adams places a premium on such a course, and there are many conditions under which it could and would be followed where it would be less obvious and more detrimental. For example, it might be that an additional track over a steep grade and a new alignment which would avoid it would cost the same. The new alignment would give greater operating efficiency, but it would require the charging off of the old line; the new track over the grade would be more costly to operate, but would leave the apparent capital unimpaired. It is such possibilities as this that are giving pause to the investors who would otherwise supply funds for the needed development of the American railway system. How far this development has so far required the abandonment of property capable of further use and having genuine capital value is indicated by available records. The aggregate capacity of all equipment has increased much faster than the increase in number of locomotives and cars. The reports of the Interstate Commerce Commission only show this information for the years 1902 to 1908, both inclusive. The average tractive power of locomotives in 1908 was 26 356 lb., as compared with 20 485 lb. in 1902, being an

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increase of 5 871 lb., or 28.7% per locomotive. The average capacity of freight cars in 1908 was 35 tons, as compared with 28 tons in 1902, an increase of 7 tons, or 25 per cent. Undoubtedly, the average capacity of locomotives and the average capacity of freight cars in 1908 was not less than 60% above the average capacity of 1890.

L. F. Loree, M. Am. Soc. C. E., President of The Delaware and Hudson Company, as Reporter (For United States) to the International Railway Congress, held in Paris in 1900, communicated with all roads in the United States then operating 500 miles of line, or more, relative to the capacity of cars actually in service. The result is shown in Table 12.

As a result of these improvements in roadway and equipment, the average number of tons of freight handled per freight train in 1908 was 351.80 tons, as compared with 296.47 tons in 1902, an increase of 55.33 tons, or 18.6 per cent. The average tons per freight train in 1908 was 351.80, as compared with 175.12 in 1890, an increase of 176.68 tons, or 100.8 per cent.

These improvements have not been solely or mainly for the benefit of the carriers, though there is no question that they have been prompted by railway self-interest. The new car of 40 tons capacity is but 20% longer than the old car of 13 tons, which means a great augmentation of the efficiency of the private sidings and tracks of the manufacturers, as well as the side tracks and terminals of the railway. Who would retrace the steps of progress of the last decade or of the last two decades? Yet the project to tie railway earnings to replacement cost, which makes no allowance for the costly steps in such progress, is in reality a project to tie them to their present state of development and to prohibit future progress. Nor can it be forgotten that it is an inviolable law of Nature that that which does not go forward must go backward—nothing can remain stationary.

The story of the crude millionaire who wanted to know the value of the "plant" of Oxford University, in order that he might duplicate it, is not inappropriate, and ought to have some significance to those who imagine that replacement cost would tell the story of railway values. Do they imagine, because they are ignorant of them, that a great railway organization carries no traditions of loyalty, of persistence in the face of overwhelming difficulty, of generous recognition of public needs and rights, of courageous adherence to the real interests of its shareholders that inspire its personnel and provide a genuine *esprit du corps*? Do they find no superiority in one organization over another, no systematic economies of method, no especial adaptation to economic needs that has value more genuine than any replaceable element, and is at least equally worthy of compensatory return?

If there were not abundant evidence that the railway industry is not excessively profitable, there would be more reason on the side of

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TABLE 12.—CLASSIFICATION OF FREIGHT EQUIPMENT ACCORDING TO THE CAPACITY.

Year.	No. of roads reporting (see Note).	Five tons and under.	Ten tons.	Fifteen tons.	Twenty tons.	Twenty-five tons.	Thirty tons.	Thirty-five tons.	Forty tons.	Forty-five tons.	Fifty tons and over.	Total number of cars.	Total capacity, in tons.	Average capacity, in tons.
1880..	A-7	38 399	131 988	447 270	89 420	.....	.....	.....	.....	.....	.....	53 733	707 077	13.2
	7	38 399	131 988	447 270	89 420	.....	.....	.....	.....	.....	.....	53 733	707 077	13.2
1890..	A-7	16 450	71 932	182 175	651 740	441 475	548 670	.....	4 000	.....	50	91 231	1 916 492	21.0
	B-13	16 450	72 082	240 900	933 040	624 125	688 100	.....	4 000	.....	50	119 513	2 528 747	21.2
1898..	A-7	1 145	34 088	144 795	629 780	734 350	842 640	.....	4 000	.....	.....	102 315	2 390 798	23.4
	C-13	1 145	34 238	255 795	993 840	947 500	1 112 070	.....	4 000	.....	.....	145 440	3 348 588	23.0
1895..	A-7	355	13 978	120 435	589 140	743 975	1 011 030	70 000	4 000	.....	50	104 495	2 552 963	24.4
	D-15	355	20 863	245 709	1 136 320	1 103 100	1 493 760	70 000	4 000	.....	50	171 807	4 074 217	23.8
1897..	A-7	20	6 462	92 535	555 980	761 150	1 224 030	74 865	4 400	450	150	108 118	2 720 042	25.2
	E-16	20	9 407	183 189	1 029 756	1 089 300	1 822 530	183 190	4 440	450	150	174 315	4 322 432	24.8
1898..	A-7	.....	1 540	94 275	523 080	721 425	1 314 840	75 320	4 480	270	50 950	108 559	2 786 180	25.7
	F-27	63 565	9 491	418 551	2 190 360	1 654 850	4 831 170	88 515	8 840	270	104 700	385 765	9 409 918	24.4

NOTE.—A—Figures cover only these roads:
Reporting for 1880 and all other years, viz.:
Allegheny Valley
B. & M. R.
C. of G.
G. R. & I.
Penn. Lines W.
Phila. & Reading
Wis. Cent.

B—Includes roads under "A," also:
Ches. & Ohio
C. G. W.
M. K. & T.
N. D. & C.
Phg. & Western
Vandalia

C—Includes roads under "A," also:
Ches. & Ohio
C. G. W.
Mich. Cent.
M. K. & T.
N. D. & C.
Phg. & Western

D—Includes roads under "A" and "B," also:
Mich. Cent.
Southern Ry.

E—Includes roads under "A" and "C," also:
C. R. I. & P.
Seaboard Air Line
Southern Ry.

F—Includes roads under "A" and "B," also:
Ann Arbor
B. & M.
C. R. I. & P.
C. St. P. M. & O.
Grand Trunk
Lehigh Valley
Mich. Cent.
O. R. R. & Nav.
Penn. R. R.
P. B. & L. E.
Seaboard Air Line
So. Pacific
Southern Ry.
Union Pacific

TABLE 13.—STATEMENT OF RETURN ON INVESTMENT IN ROAD, EQUIPMENT, ETC., FOR ROADS IN THE OFFICIAL CLASSIFICATION TERRITORY, FOR ELEVEN YEARS ENDED JUNE 30TH, 1909, ALSO FOR THE YEAR 1890.

Year.	Cost of road.	Cost of equipment.	General expenditures.	Material and supplies.	Total.	Operating revenue.	Operating expenses.
1909	$4 357 455 101	$686 116 206	$50 586 812	$75 550 135	$5 169 708 254	$1 032 285 890	$700 694 007
1908	4 306 902 038	669 751 320	51 324 157	86 201 748	5 114 179 263	1 049 545 984	746 575 094
1907	4 438 582 438	587 697 733	.....	91 923 338	5 118 143 509	1 141 224 116	794 998 803
1906	4 269 066 800	513 028 004	.....	80 479 333	4 862 574 137	1 044 552 909	714 461 452
1905	4 110 883 904	492 498 488	.....	65 875 071	4 669 257 463	944 865 659	658 337 498
1904	3 906 766 459	461 941 677	.....	72 240 521	4 440 948 657	899 868 519	636 217 217
1903	3 830 580 776	426 822 318	.....	64 458 257	4 321 861 351	871 697 611	601 864 284
1902	3 744 205 552	389 909 755	.....	50 565 290	4 184 680 597	782 975 559	528 681 892
1901	3 682 894 343	378 545 580	.....	47 746 178	4 109 186 101	730 590 144	491 657 899
1900	3 620 630 187	377 156 700	.....	49 940 838	4 047 727 725	698 368 829	467 462 093
1899	3 566 223 557	351 902 957	.....	31 162 907	3 949 289 421	610 724 301	413 390 359
Total 11 years	$43 834 191 155	$5 335 310 738	$101 910 969	$716 143 616	$49 987 556 478	$9 806 639 521	$6 754 340 598
Average 11 years	3 984 926 469	485 028 249	9 264 634	65 103 965	4 544 323 317	891 512 684	614 030 963
1890	$2 927 221 233	$283 407 139	.....	$35 262 205	$3 245 890 577	$524 767 906	$348 388 268
Total 12 years	$46 761 412 388	$5 618 717 877	$101 910 969	$751 405 821	$53 233 447 055	$10 331 407 427	$7 102 728 866
Average 12 years	3 896 784 365	468 226 489	8 492 581	62 617 152	4 436 120 588	860 950 619	591 894 072

TABLE 13.—(*Continued.*)

Year.	Net operating revenue.	Net revenue from outside operations.	Total net revenue.	Taxes.	Operating income.	Operating ratio.	Operating income. Percentage to cost of road, cost of equipment, material, and supplies.	Mileage of line owned.
1909	$331 591 883	$2 425 726	$334 017 609	$37 397 973	$296 619 636	67.88	5.738%	56 563.41
1908	302 970 890	3 446 600	206 417 490	36 021 974	270 395 516	71.13	5.287%	56 328.79
1907	346 225 313	.....	346 225 313	35 876 148	310 349 165	69.66	6.063%	56 415.25
1906	330 091 457	.....	330 091 457	34 863 314	295 228 143	68.40	6.071%	55 990.12
1905	286 468 161	.....	286 468 161	27 675 211	258 792 950	69.68	5.542%	54 963.20
1904	263 651 302	.....	263 651 302	28 091 468	235 559 834	70.70	5.304%	54 643.50
1903	269 833 327	.....	269 833 327	26 537 954	243 295 373	69.04	5.630%	53 873.11
1902	254 293 667	.....	254 293 667	25 297 465	228 996 202	67.52	5.472%	52 980.70
1901	238 932 245	.....	238 932 245	23 797 264	215 134 981	67.30	5.235%	52 911.46
1900	230 906 736	.....	230 906 736	22 616 893	208 289 843	66.94	5.146%	52 495.25
1899	197 333 942	.....	197 333 942	21 692 694	175 641 248	67.69	4.447%	52 009.98
Total 11 years	$3 052 298 923	$5 872 326	$3 058 171 249	$319 868 358	$2 738 302 891	68.88	5.478%	599 174.72
Average 11 years	277 481 721	533 847	278 015 568	29 078 941	248 936 627	68.88	.....	54 470.45
1890	$176 379 638	.....	$176 379 638	$14 753 550	$161 626 088	66.39	4.980%	43 094.73
Total 12 years	$3 228 678 561	$5 872 326	$3 234 550 887	$334 621 908	$2 899 928 979	68.75	5.448%	642 269.45
Average 12 years	269 056 547	489 360	269 545 907	27 885 159	241 660 748	68.75	.....	53 522.45

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those who continually put forward new schemes of restriction; but, not only is such evidence ample, but there is no evidence of any sort tending to establish the contrary. Limiting the inquiry to the region east of the Mississippi and north of the Ohio and Potomac Rivers, commonly known as Official Classificaton Territory, the statement in Table 13, based on the book cost of railways, with their equipment, supplies, and materials on hand, is instructive. The data are from the reports of the Interstate Commerce Commission.

The amounts shown in Table 13 as "operating income" are, as should be remembered, those earned, and not those distributed as interest on bonds and dividends on shares, which were necessarily much smaller. Bearing this in mind, it is significant that the percentage of such operating income to cost of property has not but once in the last twelve years, the most prosperous duo-decade in the Nation's history, exceeded 6%, and then only by a very small fraction; and that the average for the whole period is less than 5½ per cent. Every one knows that the real value and the actual cost of the railway property in this region greatly exceeds its book cost, so that these percentages are undoubtedly much in excess of the real rates of net earnings to value or cost of property.

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P. E. GREEN, ASSOC. M. AM. SOC. C. E. (by letter).—It is not often that there is presented to the Society a paper which shows such thoroughness of understanding of a difficult problem, and as much real experience in its solution, as is manifested therein; and the author is certainly to be congratulated on such a logical and forcible presentation of the subject. There may be some points on which engineers who have been engaged in such work cannot agree with him; but certainly it cannot be said that he has not argued very clearly and logically on nearly all the debatable questions.

Those who have not had actual experience in making a valuation of a railway company's property cannot have any idea of the enormous amount of detail and labor necessary to make such a compilation of any real value. It simply means that every detail of every structure of whatever kind must be investigated, together with the various considerations covering "intangible values," which the author has so ably discussed.

The writer was fortunate enough to be employed on the valuation of the Chicago and Northwestern Railway property in Minnesota in 1906, and possibly some details of the manner in which the actual field work of the survey was done may be of interest.

The work consisted of making a compilation from records, or from actual surveys when necessary, of about 625 miles of railway property, including several important terminals. The property had been built between 1860 and 1901, mostly in the early part of this period. The portions which had been constructed during the latter

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After examining all the old records very thoroughly, and endeavoring to get some order and information out of them, it was decided that the only way to do the work properly was to make a complete survey and valuation of all the physical property. Several field parties were organized and also an office force, about twenty men being put on the work. The parties ran levels for profile purposes, cross-sectioned cuts where necessary, noted evidences of clearing and grubbing, of the character of the cuts, and the disposal of the material, examined the ballast for depth and character, examined the rails for age, weight, and condition, and noted the kind and condition of the fences, gates, farm crossings, planking, whistle and highway-crossing posts, culverts, bridges, and in fact every detail of construction. Advantage was also taken of the survey to re-station the lines, to paint such stations on the rails, and to set permanent posts, so that afterward the stationing could be picked up at any time with little trouble.

In this way there was accomplished much work of value to the railway company, for which there had been a demand by the division officials for years, but which had not been done because of lack of men and money.

No attempt was made to assign depreciation, as regards the rails; this was determined afterward, from the age of the steel in the track. It was necessary, however, to make quite a thorough inspection of the ties, and to note their condition, as they were replaced year by year singly as they wore out. Almost every conceivable kind of timber had been used for ties at one time or another. Treated and untreated ties lay side by side; and thus there was great difficulty in classifying them with regard to the kind of timber. With bridge ties and timbers of frame and pile bridges, there was not so much difficulty, as they were open to inspection, and had been inspected twice yearly by the Division Engineer and the Superintendent of Bridges and Buildings, and accurate records of their condition and renewals had been kept. The depth and condition of the ballast also varied very widely.

In a very short time all the men on the survey became well acquainted with the character of the work they had to do, and, as the work went on, the progress of the party day by day was very much

more rapid. At the beginning of the survey, a progress of 6 or 7 miles of single track was considered a very good day's work; at the end of the survey, the parties were making from 12 to 15 miles per day. Mr. Green.

There was considerable difficulty in setting proper values on the hundreds of buildings, large and small, owned by the railroad. Most of these buildings had never been constructed from plans, and it was difficult to calculate what they had cost originally, and what it would have cost to build them at the time of the survey. However, time books were searched, and the contents of the buildings in board feet were calculated, and, while in many cases their age was not known from any records, it was nearly always possible to find out from somebody just when they were erected.

As intimated before, the railway company derived much actual benefit from the work, outside of the accurate knowledge obtained as to the value of the property itself. Steel charts, bridge records, etc., were established, and profiles, stationing, continuous bench-levels, etc., were all re-run or re-established; thus making the engineering work of the future more consistent and uniform, and enabling more work to be done with a smaller force. New maps of all the station grounds and terminals were obtained, and all the records were put in better shape than they had ever been before.

Examination of some of the old terminals brought to light many strange and out-of-date conditions. Old wrought-iron rails of antiquated pattern, old cast-iron frogs, etc., of a pattern which had not been in general use for fifty years, were found in the track. On some of the little-used sidings, the old wrought-iron rails were so worn that the tread of the rail was entirely gone, only the web remaining to carry the traffic, and such rails were still in use.

In such a valuation, also, many items, some of considerable magnitude, were found which were extremely difficult to classify and assign to their proper place. Such a one, for instance, as a soft, sand rock deposit beside the track, which for many years had furnished engine sand. Many thousand cubic yards of this material had been excavated, but it had not gone into the roadbed as ballast, or to make fills, or to widen embankments. It would hardly have been proper to classify such excavation as grading, for it was an item of engine maintenance and train operation. This is only one of numerous problems which had to be solved.

After all the survey had been made, most of the work of compilation had to be done. Some of it had already been done in the office by the small office force, but the great mass had to be done by the men who did the work in the field. This task was of almost incomprehensible magnitude. There were thousands and thousands of items, and such a great mass of figures that the ordinary man would become lost

Mr. Green. in the maze. The data had to be checked and re-checked by men who were not accountants, and sometimes most ludicrous mistakes were discovered. However, it was at last accomplished, and the writer's recollection of the "Present Value" of the Chicago and Northwestern property in Minnesota is that it was somewhat more than $23 000 000 for the entire mileage (about 625 miles), or an average of about $37 000 per mile of track. Hardly any of the mileage would be called high-class or trunk-line track, but most of it might be classed as second-class or important branch-line railway.

Mr. Kuichling. E. KUICHLING, M. AM. SOC. C. E. (by letter).—This paper is a very valuable addition to the literature of a comparatively new subject that is rapidly attaining great political importance, and it gives abundant evidence of deep research and thought by the author. The reasons for determining the true value of such properties, as well as the general principles of making the valuation or appraisal, have been set forth so clearly and convincingly that little can be added in this respect; hence, there is room for comment only about details.

One of the perplexing questions is the determination of the proper value of the right of way and real estate of a railroad. The land was originally acquired at a certain cost, essentially for public use, and in the course of time its value, as determined by reproduction cost, usually becomes greatly increased by the development of the adjacent land by its various owners. Without the railroad, such development and appreciation of land values would probably not have occurred, and, therefore, it has been argued by many persons that, for taxation purposes, the railroad lands should be appraised at only their original cost, while, for capitalization purposes, they should be appraised at a value measured by that of the adjacent land at the present time. This claim is based on the theory that the railroad is like any other piece of public work, such as a canal, highway, or pavement, which is built for the use of the public, and on which no tax is levied by State or municipality. On the other hand, it has been held by some of our Courts that a proper valuation must take into account the appreciation or depreciation of land values; but, as the opinion of a Court is not unalterable, the soundness of this doctrine cannot be regarded as permanently established.

The author states* that there can be no serious objection to this doctrine in relation to rights of way in the country and small towns, although he admits that it is subject to exceptions in the case of cities and terminal and dock properties. It will be of great interest to learn his reasons for making such exceptions in the case of the most costly lands, and whether the valuation of such lands should be more or less than that of similar adjacent lands used for other purposes. From the context the inference may be drawn that the valuation should be some-

* Page 139.

Mr. Kuichling.

what higher than that of adjacent similar land in the case of a steam or interurban railroad, because its holdings form a continuous strip; but to the writer this reasoning does not appear satisfactory. The statement of the Court, that "the value of land depends largely upon the use to which it is put and the character of the improvements upon it," does not necessarily involve a higher valuation of the property than its cost, and it is quite conceivable that the actual value of the property after being taken by a railroad may be much less than it was before. The only reason in such a case for maintaining the purchase price is to conserve the general valuation of the adjacent similar real estate.

In dealing with the subject of depreciation, the author has been very brief, as he did not consider it essential for the purposes of the paper. This is to be regretted, as depreciation is an important feature in every valuation, and so few trustworthy data concerning it are available. The value of the paper would be greatly enhanced if the author would give the assumed average life of the principal components of a railroad, based on some definite traffic, and normal grades and curves. Much diversity of practice in this respect prevails, and the final judgment of the numerous experts who were engaged in the Michigan valuations cannot fail to be of great interest. The same remarks are also applicable to the unit prices adopted for construction and equipment.

The subjects of expenses for organization, engineering, administration, contingencies, and non-physical values are treated very thoroughly by the author, and particularly interesting is his discussion of the complex question of franchise value. After quoting from numerous judicial opinions, he reaches the conclusion that the franchise simply protects the owners of the property in their enjoyment of the earnings, and that its value merges into the "fair value" of the property and becomes inseparable from the other non-physical elements of value; also, that the aggregate non-physical value of the property depends only on the net income for a period of years. This method of estimation certainly has the merit of being simple, rational, and free from all hypothetical considerations. It is, however, obviously governed by the rates charged for the services rendered, and if these are likely to be altered at any time by governmental action, a corresponding alteration in the "fair value" of the property will take place.

This consideration brings us at once to the intricate question of reasonable rates, which involves the matter of reasonable design and construction of the property. In most cases the working capacity of the plant must be much greater than the average annual demand for the service performed, as so-called "peak loads" of relatively short duration must be provided for. The magnitude of these peak loads, however, varies with the subsequent development of the territory, which is necessarily conjectural; hence it follows that a comparatively large

Mr. Kuichling.

amount of capital is often invested in an enterprise for the purpose of taking care of such anticipated temporary demands, and on this investment a "fair return" should be granted. This condition is particularly noticeable in municipal water-works plants, where provision must be made for supplying water for fire service to an extent which may be several times greater than the normal hourly rate of consumption. In the case of railroads, such demands can usually be met by adding to the rolling stock at moderate expense, while in a water-works the outlay is relatively greater because the entire plant must be adapted in the outset to the anticipated maximum delivery in the course of a comparatively long period of time.

The problem of rate-making has been excluded by the author from his present paper on valuation; but, inasmuch as he is so well qualified for the task, and also because the non-physical value of the property depends mainly on the rates obtained for the service rendered, it is hoped that he will deal with this feature in a subsequent paper, thereby bringing out a discussion on the obscure subject of "fair return." It is noticeable that these phrases occur frequently in judicial opinions, but the fundamental principles on which a definite conclusion should be reached are seldom set forth clearly.

Mr. Dana.

RICHARD T. DANA, M. AM. SOC. C. E. (by letter).—The solution of this problem includes practically all the factors in the general subject of economics, in which engineering occupies a large but by no means preponderant part. Mr. Riggs has done some very valuable and pioneer work in contributing this paper at this time; and the writer, in calling attention to what appears to be a radical error in it, does not wish to be taken as attempting to detract in any way from its great value as a whole. It is most important, in the inception of such an investigation, on the part of the members of this Society, to remove from the subject the stumbling blocks as they appear.

The author makes the following statement:

"It is true that the 'value' of a property is an unstable figure, subject to fluctuations due to natural or artificial causes, and that a material change in value may occur suddenly, but the 'value' of any given property on any given date is, or should be, from an engineering standpoint, a definite sum which may not be varied or changed to suit the whim or will of the people for whom the work is done."

The fundamental conception of a value is so important in an investigation of this kind that it is worthy of careful and thorough discussion.

The appraisals which the writer has had occasion to make have generally been for one or other of the following purposes, namely:

(I) Taxation, in the interest of the community or corporation taxed;

(II) Bonding, in the interest of the banker or representative of persons who contemplated lending money on the property;

(III) Rate-making, in order to determine what was a fair amount of money that the property should be allowed to earn for the owners. Mr. Dana.

Now, in general, a proper value for any property for any one of these purposes is different from its proper value for any of the others. This proposition is of immense significance, for the reason that, if the value for the property arrived at, on one basis, be accepted and applied for one of the other purposes, it will inevitably result in gross injury and financial loss to some one.

In attacking this problem, one must be careful to take the correct standpoint, which is not necessarily that of engineering. Engineering science is indispensable for a large part of the work, but there are other indispensables, which would not ordinarily be recognized as engineering. The writer takes the view that engineering is a part of economics, rather than economics being a part of engineering.

To illustrate this point, consider two objects, one of which is concrete and simple and the other more complex.

(1) A steam shovel belonging to a railroad, costing $10 000, new;

(2) The entire railroad as an operating entity.

Assume for (1) that the shovel has been purchased recently, is in perfect condition, and that the railroad has some work for it to commence on as soon as it can be properly installed. What is its:

(I) Taxable value,

(II) Bonding value, and

(III) Rate-making value?

(I) The tax assessor cannot properly appraise it at $10 000, because it certainly would not sell for that sum, and if the community should have to sell it for taxes the actual return minus the charges would be so much less than the $10 000 that the community's books would show a heavy loss; and this practice, if largely indulged in, would bring the community into financial straits. The community must be exceedingly conservative in its estimate, for this very reason; and, therefore, it has been customary, almost universally, to tax such articles practically on their sale value at what might be called panic prices. The company which sold the shovel to the railroad would not buy it back two days after the sale for more than the original price minus what that company considers its selling charges, say 20%; so that, in this case, even if a customer were at the door, the shovel would not be worth more than $8 000, and a fair tax appraisal could not consistently be more than $8 000 minus charges of, say, $250, or $7 750.

(II) Assuming that the railroad is a very small one, that it wants to borrow money, and desires to put up the shovel as collateral for the loan. What would be its loan value to the lender? In considering this point, it is necessary to assume that no aid is rendered by the credit of the railroad itself, but that the protection for the loan is to be

Mr. Dana.

furnished by the shovel only. Now, the banker will reason that, in the event of the note remaining unpaid, he will have to sell the shovel to reimburse the bank for its loan, and he will be required to consider the matter on a conservative basis. He cannot lend on the shovel up to its full value, for in the first place it is not a "negotiable security." If it were a security, with a free market on some stock exchange, he would probably lend to the amount of 80% of its value, but a steam shovel in a sand bank on a railroad is by no means as convenient of exchange, nor as easy to foreclose on as a stock certificate in a banker's box; therefore he will lend, or he ought to lend, less than 80% of its sale value, minus the selling charges. If he lends more than this, he is lending on the credit of the owner of the shovel rather than on the shovel itself. Granted that the maker of the shovel is willing to buy it back at its full selling price less the selling cost, the maximum loan value of the shovel would be a little less than 64% of its purchase price, or $6 400. To lend more than this on the shovel would not be conservative banking.

There is another bonding or loan value to this shovel, when it is considered as part of the assets of the railroad, the bonds of which are to be held by the banker, under which circumstances a higher value than $6 400 would be admissible.

(III) If the value is to be determined with a view of ascertaining what is a reasonable figure that the owner of the shovel ought to be allowed to earn as a public utility organization, the problem is entirely distinct from the foregoing two cases. Assume that the railroad is entitled to earn at least 6% on its investment in the shovel. Now, its investment is $10 000, because that is the money that it cost; and nothing had been credited to its account, since the shovel had just been purchased and had not yet done any work. The shovel cannot be considered as being worth more than its cost, and it can easily be shown it is not worth less for rate-making purposes.

These three illustrations, which are very briefly outlined, should demonstrate the fact that there is almost no relationship between any two of the different kinds of value which are being considered.

Now, from the standpoint of the railroad as a whole:

(I) Should railroad property be taxed on the basis of what the entire railroad would bring on a foreclosure procedure? Obviously not, because the railroad is taxed in sections. The Town of Squedunk will tax the portion of the railroad that lies within that town, and will have considerable difficulty in putting down as security for its own bonds the locomotives and cars which go through once a week or twice a day at 40 miles per hour. To cover partly the flitting assets, it taxes the railroad on a franchise value. It may tax a railroad's land on the same basis that it taxes land owned by private individuals, notwithstanding the fact that when the railroad buys the right of way it

generally has to pay more money per acre than the householder or the farmer. This unit cost to the railroad may be two or three times that to the farmer, yet the writer has never heard of a community attempting to tax railroad property two or three times as heavily as adjoining property used for private or commercial purposes. Mr. Dana.

(II) On the other hand, this same property is an absolutely sound asset for the railroad, and the railroad probably bought the property from the proceeds of the sale of bonds. If the public service commissions were to rule that the railroad may be allowed to issue bonds only to the amount of the taxable value of the property which is to be held as security for the bonds, the result would be an absolute paralysis of railroad construction. A bond is an obligation to pay so much interest for so many years, and to pay back the principal at the end of its term. The bondholder is interested in the absolute regularity of his interest, and in the security that lies behind the principal, and it is to-day the custom of banking houses to consider a bond well secured when, in a territory of reasonably rapid growth, the principal is earning say twice the interest on its bonds, and when the cost of reproduction is in excess of the amount of the bonds, provided that the property is in good physical condition. If it should be necessary to foreclose on the bonds, it is then reasonable to suppose that some one else will buy it in for at least the amount of its bonded indebtedness. What can this possibly have to do with the taxable value of the track in the Town of Squedunk? One may be 1.5 times the other, or three times the other, depending on a multitude of circumstances.

(III) The value of the property for rate-making is a complex one to determine, and, of course, there is no opportunity for a full discussion of it here. One point, however, will serve to establish thoroughly the difference between this and taxable or bonding value. If the community is prosperous and the business is a good one and honestly managed, the railroad ought to be allowed to earn a reasonable percentage, say, at least 6%, on what has been put into it. If the community should decree otherwise, then people will not build railroads for investment purposes, and all will lose money. Now, it is a well-known fact that a new railroad's earnings have to grow for several years before they are on a normal basis, and part of what the owners of the property have put into it is, for example, the interest on its cost before its earnings are on a normal basis. This may amount to a considerable percentage of the original construction cost of the property, if the business is several years in developing. Granted that the community ought to allow the property to earn a reasonable interest on what has been put into it, then the rate-making value will be very much larger than the sum of the taxable valuation of all its different parts. It will also be much greater than its bonding value, because, as a bond proposition, it can borrow money up to a limited percentage of what it is actually worth.

Mr. Hammond.

GEORGE T. HAMMOND, M. AM. SOC. C. E. (by letter).—The engineer called on to fix the valuation of public service corporation property has so little engineering literature on this special subject to guide him that he must feel grateful to the author of this excellent paper for adding so much of a kind that is very desirable.

Estimating the cost of an engineering structure in advance of its construction is one of the most ordinary professional duties, but how difficult it actually is, and how much engineers differ with one another in their estimates on the same structure! Perhaps there is no professional duty which calls for so much study and so much experience, or which tests so closely the ability and capacity of the engineer. How seldom professional estimators agree with each other; or designing engineers with contracting engineers; as witness the bids received at the public lettings of contracts when compared with the engineers' estimates of cost; and, if this is true, which no one will attempt to deny, how much more so is it probable that estimators will disagree when they attempt to place a value on works already completed, and in service, perhaps, for many years, in which various changes in value have occurred, and in which questions of fact are mixed with legal questions involving legal rights, as well as financial questions.

The tendency in all such valuations appears to be a mixing up of things in general—like the witches' stew. Everything goes into the pot and is boiled together until all becomes soup, at least until the official commission, like the witches, considers it done and ready to be served up in the form of a report. It is then observed that the substance served out is of a complex nature; that the valuation of engineering structures has become mixed with other and uncertain values; that the whole value, as stated, is, after all, little better than the commission's opinion of the value; and that another commission would reach a different conclusion.

The author states that the valuation of corporation property:

"Should be the honest judgment of the men composing the commission, as to the actual cost of reproduction, present physical value, or 'fair value,' and should be ascertained by a systematic and scientific method which takes into account all the facts concerning the property, its physical value, its strategic location, its operating revenues and expenses, and its franchises, rights, competition, opposition, and all other tangible or intangible elements, which would affect values. The method of valuation should be such as to minimize or entirely eliminate all differences due to errors of personal judgment."

This, it seems, complicates actual present values with conditions which might, or might not, continue. Outside of the physical valuation of the plant, which offers the easiest problem presented, how can one fairly put a value on operating expenses and revenues, which might be affected favorably or advisedly by good or bad management,

and by numerous other complex and almost incomprehensible circumstances. Mr. Hammond.

The tendency of all such commissions seems to be to confuse together and mix up some things which are logically separate. Thus, the value of the plant and franchise, good will, and present investment or income value, etc., are too often taken together. The value of the plant is dependent on the cost of reproduction, and also the depreciation of the structures, as engineering structures, and should be based on present prices for which the work could be replaced, minus the depreciation, which is a question of engineering judgment and experience. The other items of value are largely dependent on the situation of the plant and its prospects as an income-producing property, and this again is a matter of opinion, in which the opinions of financiers and investors are sometimes of more moment than those of engineers. The opinion of lawyers as to the value of the franchises and the cost of the legal complications possible or probable must also enter into any seriously worthy opinion as to value.

The few salient lights in the picture of valuation, presented by the author, serve especially to reveal the darkness which involves the whole subject of valuation, estimating, and the use of cost data for such purposes, and to suggest that, with all the wonderful progress on the theoretical side of the profession, engineers have as yet advanced but little in this division of the practical side—cost data, valuation, and estimating. Engineers cannot compare the results of different estimators and appraisers without sorrow and even shame for their ignorance, or their incapacity to agree in the application of scientific principles and the results of practical experience to this branch of their work.

At present we would seem to be a long way from a method of valuation, "such as to minimize or entirely eliminate all differences due to errors of personal judgment."

The method described as having been used by Professor Adams seems to be at least an advance toward a logical and rational method of getting at the value of corporation property, but it must be acknowledged that we are as yet a long way from a perfect method of appraisal, even of the physical values, to say nothing of the non-physical. He held that as nothing visible or tangible gave support to the latter value, it must be determined on the basis of information secured from the income accounts of the company. This method of measure, it would seem, is not unlike the celebrated dictum on the length of the Chancellor's foot, "some Chancellors have a long foot, and some an indifferent foot, and some a short foot"; therefore, a great English Chancellor says, "the length of a Chancellor's foot should not be taken as a measure of rights in equity." Thus, if the income of the company is to be taken by the appraising engineers, or the gross income, it may have to be given a different interpretation from the net income, and

Mr. Hammond.

if the surplus earnings depend on transient causes or on excessive rates for service, it will lead to a totally erroneous conclusion. The same may be said if the rates for service are too low, or if the company is badly managed, or is carrying a great deal of "dead wood," either in the form of property or of servants. Therefore, it seems evident that he who attempts to follow this method of appraisal must possess almost superhuman judgment of present conditions, and prescience to forecast the future, as well as a grade of wisdom and knowledge of existing conditions of trade and industry which may be also characterized as superhuman. In order to apply Professor Adams' method justly, we must know whether the company is wisely managed, whether its income is a fair income, whether its physical property is all useful and needful, whether its service is what it ought to be as to efficiency and economy, etc. We must assume an ideal condition of commerce and industry, and of property value and management, and then appraise the company's property by comparing it, consciously or unconsciously, with this ideal. Possibly this is the best method devised so far, but surely it leaves a great deal to be desired; and it is difficult to see how different engineers, on different sides of the question, representing different interests, can find any common ground of agreement in Professor Adams' method. Under such circumstances, engineers are likely to differ in their results as much as the length of the different Chancellors' feet.

Mr. Metcalf.

LEONARD METCALF, M. AM. SOC. C. E. (by letter).—Mr. Riggs has done engineers, and more particularly those interested in valuation works, a genuine service in presenting to the Society this admirable paper.

No shrewd observer can fail to recognize the increasingly insistent demand of the public for greater publicity in the accounting, and a larger measure of governmental control in the operation, of public service corporations. In its best form, such control will be welcomed by the corporations, as giving greater stability to investment in such property; in its worst, it may prove a serious limitation to prompt development of the best standards of service. In the water-works field, the anti-corporation movement has resulted in taking over by the public many such plants. It does not seem likely, however, that we are ready to go farther in the railroad field of operation than to demand reasonable regulation of such corporations.

While the writer has had no experience in railway management or valuation, he has devoted much time and thought to the valuation of, and determination of fair-rate schedules for, water-works properties; therefore, what he may have to say in comment on this paper may be assumed to have direct application to water-works valuation, and to railroad valuation only as the similarity in the public service rendered by these corporations may imply.

Mr. Metcalf.

In the main, the writer subscribes heartily to the views expressed by the author and the temperate way in which he has expounded them. Space forbids discussion in detail of all the matters alluded to and so well covered by Mr. Riggs. On one important subject, however—the inclusion of the going value, or going concern value, of public service corporation property, in the intangible property values, rather than in physical plant value, and the consideration of it as an intangible value rather than as a real and substantial item of cost to the public service corporation—the writer differs from the author. It is clear, from what Mr. Riggs has said, that this is debatable ground, and, from the care and fairness with which he has expressed his views on this subject, one might almost be led to infer that he invites attack on it. It is in no carping spirit of criticism, however, that the following views are expressed.

As the writer has recently submitted to the Publication Committee of this Society a paper on the "Going Value of Water-Works," written by him in collaboration with John W. Alvord, M. Am. Soc C. E., in which a detailed discussion of this subject will be found, only enough will be said to outline clearly his point of view.

The author says:

"The physical property is that which enables the corporation to do business. Without physical property it could not produce the commodity which it sells. The amount of money actually invested in acquiring that physical property represents the measure of capital on which it is morally entitled to earn interest and profit; and, in the stage of promoting and financing the enterprise, all hope of earnings is based on the amount of money required to construct the property."

He also says:

"It would seem reasonable to say that this difference between the physical value and the value based on earnings represents the 'good will,' 'established business,' or 'going value,' and all other non-physical elements of value."

In referring to going value, he says:

"* * * Yet, to fix a value on it by the method described by him [Mr. Alvord] involves going into the realm of conjecture and speculation to a degree that could never be sustained. * * * It can be readily seen that the physical present value is not always—indeed, is not often—the 'fair value.' The 'fair value' may be more, or less, than the present value of the physical property."

"* * * Is it not, then, proper to conclude that the non-physical or intangible value, composed of all these various elements of value, can only be determined absolutely by a study of the earnings and operating expenses? * * *"

He also says:

"The contention that all the different elements of non-physical value merge into one intangible value, not capable of separation, will

Mr. Metcalf.

doubtless be objected to by many engineers and corporation managers. * * *"

"The writer does not concede that 'going concern' is a proper element to consider in the physical value, as it does not represent any part of the cost chargeable to capital, and the physical valuation should be confined to the determination of capital invested."

Quotations might be multiplied. Those cited, however, will suffice to recall the author's view, and to make clear the point with which issue is taken.

Is Mr. Riggs right in his contention that going value is in fact an intangible value; that going value is not an element of real cost to the company, involving investment of capital; that going value, therefore, should not be included in physical plant value; and that the company is not morally entitled to earn interest and profit on it?

The writer contends that going value is as real an element of cost, in the property of any public service corporation, as is the cost of any portion of its physical plant. It pertains, however, to the business, rather than to the physical plant, of the corporation.

Whatever the difficulties of its computation may be, whatever the methods used—whether that adopted by the Wisconsin Public Service Commission (which is essentially one of determining the original cost of the going value and not its reproduction cost), or whether that perhaps first outlined by Mr. Benezette Williams and George H. Benzenberg, Past-President, Am. Soc. C. E., in the Middle West, and by William Wheeler, M. Am. Soc. C. E., in the East,* a method which seeks to determine the reproduction cost of the going value, rather than its original cost—the going concern value has come to be recognized, by water-works appraisers at least, as a substantial element in the cost of the plant, and hence as differing essentially from the franchise element or so-called unearned increments of value.

Is not going value in a "between" class—a middle ground between tangible and intangible values—tangible in that it has involved real cost and expenditure of money; intangible in that it is not as readily calculated as are other reproduction cost items, is dependent fundamentally on the earnings of the company, and that there is no tangible equivalent to show for the expenditure, except the existing income of the corporation? Surely its character is quite different from that of the franchise, as ordinarily found, the value of which, while real, from the rate-payers' point of view, seems to be made out of whole cloth; in short, seems to be of fictitious value.

Certainly, the conjectural and speculative character of the computations—as referred to by Mr. Riggs—involved in the determination of going value is no excuse for failure to recognize going value as a

* Shortly after the Kansas City Water Company case and the classic decision of Mr. Justice Brewer, and since developed by the suggestions of a number of engineers, among them John W. Alvord, M. Am. Soc. C. E., whose admirable article on "Going Value of Water-Works," presented at the Milwaukee Convention of the American Water-Works Association, held in 1909, is familiar to all students of water-works valuation.

real element of cost, rather than as an intangible value. As a matter of fact, the variation in the views on going value, by engineers who have given this subject particular study, while greater than the variation in their estimates of the reproduction cost of the physical plant, is still far less than the variation in their views on franchise value. Mr. Metcalf.

As bearing on the proper basis for rate-making, the author's statement, that the "* * * physical property represents the measure of capital on which it [the public service corporation] is morally entitled to earn interest and profit * * *" cannot be admitted, equitably or legally; and it is not to be assumed that Mr. Riggs desired to imply that this sentence summed up his final views.

Are we not, however, approaching a basis of rate-making, predicated on the earning, by public service corporations, of operation and maintenance expenses, depreciation allowance, and return (*i. e.*, interest and profit) on reproduction cost of the property, less accrued depreciation, plus going value, plus a nominal allowance for the franchise and other intangible values of the corporation? Is it not possible that the recent depression in the business world has been due, in considerable measure, to the shrinkage in the values ascribed to franchise and other intangible value in public service corporation property?

If we are approaching such a limitation, it is the more important that the public should be educated to the fact—not theory, for it is a fact—that going value, or going concern value, is a real element of cost, covering an outlay in effort and money on the part of the corporation, and as such is as much entitled to earn a return (interest and profit) as is the other capital invested in plant. It is not on any items of real and necessary cost to the corporation that the public objects to paying tribute, but on the "unearned increments" and the virtual monopoly "privileges" enjoyed by the corporation and created, in large measure at least, by the public itself and by normal conditions of growth and development for which the public, rather than the corporation, was perhaps responsible—though in many cases it may be urged truly that the corporation itself, rather than the public, has been responsible for the development.

Such a basis of rating, while still dependent on sound judgment and judicial treatment, is nevertheless not beset with the speculative element involved in the capitalization theory, which, Mr. Riggs himself admits, fails as a basis of rate-making except when predicated on fair rates.

If the writer's contention, that going value is a real element of cost in the property of any public service corporation, is sound, Mr. Riggs' statement that, "It appears to be doubtful whether the Court can be construed as approving such an element of value in rate cases," and his interpretation of Judge Tayler's ruling in the Cleveland Street Railway matter,* must be challenged.

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Certainly, as applied to water-works valuation, Mr. Riggs' statement is not justified. The Maine cases clearly include going value as an element of value on which rates should be predicated; by inference, so does the Kansas City case. In the Knoxville case it was in fact allowed by the Master.

In equity it cannot be doubted that going value should be included in the base on which the returns are predicated, if, as contended, it involves real cost to the company; for the company must be permitted to earn a fair return on this cost, or to liquidate it in some way, as otherwise the corporation would suffer substantial property loss—from 10 to 20%, more or less, of the reproduction cost of its property. This would be contrary to public policy, for, with such an outlook, capital would not enter this field of enterprise, except at increased rates of return, commensurate with this added hazard. To assume such increased rates of return is to provide another means of liquidating such a loss.

As to "good will," it has seemed to the writer more proper to use this term in private competitive corporation enterprises, as applied to the element of value corresponding to the going value of the quasi-municipal or public service corporation enterprises, which latter are in effect controlled monopolies. If the term is used in its more colloquial sense, such as the effect on earnings of having, in the office of the corporation, men who meet the public pleasantly, who are good "mixers," and who are active in getting business, the value is substantially included in the consideration of the income, in the manner involved by going value determination and franchise valuation.

The depreciation question has been discussed so fully elsewhere that the writer only calls attention to the fact that, while physical and functional depreciation only are to be considered in a review of the present physical condition of any plant, in considering a fair-rate schedule, provision should also be made for contingent depreciation, covering such items as cost incident to change in street grades or construction of subways; placing structures under ground, which were previously above ground; serious loss due to injury by electrolysis, the distribution of which over a period of years rather than inclusion in the operating cost for one year, is to be preferred, alike from the public and from the corporate point of view, from the fact that it spreads the burden to be borne by the rates, and prevents violent fluctuation in prices or valuation of the public service corporation's property. The public pays dearly for all hazards. It is wise, therefore, to pursue the conservative course in providing adequate funds to meet extraordinary conditions, and to give stability to the investment of the corporation. Moreover, such funds can be carried in a separate account which can readily be watched; any excess can be credited to future reduction in depreciation account requirements, while a prolonged deficit cannot

perhaps be recovered by the corporation, in the light of the Knoxville decision. Mr. Metcalf.

The comment that no hard-and-fast rule can cover determination of proper depreciation allowances, is amply justified. In its final analysis, it is a matter of good judgment, experience, and judicial temper.

The author's statement that the organization, legal, engineering, administration, and general expense accounts, "should not be considered as affected by depreciation, as long as the property is a going concern," is not quite clear. Obviously, this is true with regard to all the early organization expenses, as these expenses are incurred once for all, and constitute a continuing asset similar to other elements of plant cost. If, however, the author refers therein also to the engineering and contingent item added to many of the reproduction cost items making up the physical property, exception must be made; for when an old structure, the life of which is gone, is replaced with a new structure, new engineering costs are incurred, and the engineering element of cost incident to the installation of the original structure no longer inheres in the plant. It, too, has passed away with the life of the structure, and, therefore, its cost should be liquidated, or provided for in the depreciation account, as well as the cost of the structure to which it was incident.

In the same way the "interest-during-construction" item is not a continuing asset, but should be liquidated with the complete depreciation of the portion of the structure to which it relates. The replacement of the structure will involve new "interest-during-construction" charges, commensurate with the time required for construction. The value of the initial "interest-during-construction" costs will have disappeared with the original structure and, therefore, should be taken care of by the depreciation account.

The method of making allowances for interest during construction, suggested by the author,* accords closely with that used by Mr. Alvord and the writer in a recent valuation of a large water-works property, in which the "interest-during-construction" charges were limited, and the contributions to depreciation account were begun, at the date on which any workable unit of the property was assumed to be available for service and to begin to earn a return on its investment cost, even though the structure, as a whole, was not assumed to be completed for a considerable period of years thereafter. Thus, for instance, it might be assumed that as soon as the supplying works in a water-works project were in operation, the investment in them and in the distribution pipe system laid up to that time, would cease to be credited further with "interest-during-construction" allowances, and would be compelled to earn interest through the water rates or income from

* Page 144.

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water supplied to consumers—the fact that the interest charge could not be wholly met, immediately at this time, being taken care of in the resulting increment in going value.

Such a theory, of course, does involve a determination of the probable order and rapidity of construction of the component parts of the property, and this is usually made, in water-works valuation, in the estimate of the reproduction cost of the property.

For the sake of completeness, in reference to the legal decisions of importance in valuation proceedings, attention is called to the Pennsylvania case, Brymer *vs.* Butler Water Company (179 Pa., 231), referred to in the closing discussion on the writer's paper on "Water-Works Valuation."*

In this case Justice Williams, speaking for the Supreme Court of Pennsylvania, says:

"By what rule is the Court to determine what is reasonable and what is oppressive? Ordinarily, that is a reasonable charge or system of charges which yields a fair return upon the investment. Fixed charges and costs of maintenance and operation must first be provided for. Then the interests of the owners of the property are to be considered. They are entitled to a rate of return, if their property will earn it, not less than the legal rate of interest; and a system of charges that yields no more income than is fairly required to maintain the plant, pay fixed charges and operating expenses, provide a suitable sinking fund for the payment of debts, and pay a fair profit to the owners of the property cannot be said to be unreasonable."

The Pennsylvania Court, therefore, in the words of William S. Wallace, Esq., recognizes the single standard:

"The Single Standard, according to the Brymer case, while acknowledging the full right of the public to regulate such public corporations, also recognizes as a prime factor its private character and the rights which accrue to it in that capacity, * * * and holds to what seems to me the only rational and practicable basis, that a fair return, after deducting the charges above enumerated, *is* a reasonable rate"; whereas, "the Double Standard basis of fixing a reasonable rate seems to accentuate the public side of the corporation and rather ignores the private element."

As to the propriety of the inclusion of a substantial recognition of franchise value as a basis for rating, the layman may well confess to perplexity, in the light of the conflicting nature of the two important recent United States Supreme Court opinions referred to—the Knoxville case, and the Consolidated Gas Company case—for, while substantial allowance was made for franchise value, in the Consolidated Gas Company case decision, in large measure apparently on account of its earlier recognition by the legislature, in the Knoxville case, in spite of legislative recognition of such value, and similar approval of

* *Transactions*, Am. Soc. C. E., Vol. LXIV, p. 94.

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the issue of securities predicated on such recognition, the United States Supreme Court failed to make similar allowance for franchise value.

The author's treatment of the unit price question and the contingency item is intelligent and creditable. Engineers are prone to make valuations based on "hindsight" instead of "foresight," on the assumption that no substantial difficulties in construction were encountered, when, in fact, substantial difficulties should perhaps have been anticipated, and may actually have been encountered in the original construction, record of them having been obliterated, however, with the lapse of time.

The author's definition of the value of a property, as the "estimated worth at a given time, measured in money, taking into account all the elements which add to its usefulness or desirability as a business or profit-earning proposition," suggests the advisability of recognizing the other side of the ledger by modifying his statement so as to read: "* * * all the elements which add to, 'limit, or detract from' its usefulness or desirability as a business or profit-earning proposition."

While recognizing the author's view, that there is no separate and independent method of determining franchise value, which is not based on the determination of the value of the property as a whole, by capitalization methods, it must be recognized that going value may be determined independently, and may have a positive value, even though the property as a commercial whole is worth less than the sum of the physical value and the going value.

The Court, appraisers, and the author, alike recognize that there is no one method of valuation of universal application. First cost, reproduction cost, reproduction cost less depreciation, commercial value determined by capitalization, worth of the service to the consumer, and market price of the property, if such exists, all have their weight, in varying degree in different cases. Whatever may be said of, for, or against, these several methods of valuation, relates rather to their significance, and the weight which should attach to the results obtained by them, as evidence of value and of the effect of the modifying local conditions, than to the soundness of the methods themselves.

In this connection it may be of interest to refer to a recent valuation of a water-works property, in the appraisal of which the writer chanced to participate, in which there was finally placed before the board of appraisal a summing up of:

1. The original cost;
2. Reproduction cost less accrued depreciation, plus going value;
3. The worth of the service to the consumers, based on a stated assumption of reasonable increment in value in excess of actual cost, upon which a return (or interest and profit) should be earned;

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4. The commercial or capitalized value, on certain assumptions based on present conditions, and also on possible future conditions which might be involved in a renewal of the City contract, which was to expire within two years.

That these determinations of value, from different points of view, had an influence in moulding the opinion of the individual appraisers, there can be little doubt; yet it is probably equally true that in no case was like weight attached to the several items or bases of valuation. Nevertheless, in the final valuation, the consensus of opinion as to the value of the property, as a whole, was remarkably close, the extreme variations in opinion being approximately 8%, more, or less, than the final appraised valuation.

Attention should also be called to the necessity, in any valuation by capitalization of income, such as that outlined by Mr. Riggs and used by Professor Adams in the U. S. Government Valuation of Railroads,* of determining whether the plant or property is in what might be termed an over-built, normally developed, or under-built condition; in short, whether the investing public has correctly gauged its momentary physical condition with reference to its bearing on the rates, and whether the earnings are in fact inadequate, commensurate with the service rendered, or excessive. In the long run, due weight will be given to these facts; in a brief period, they may be incorrectly gauged. In water-works properties, unfortunately, there is rarely, if ever, a market price of the securities which can be said to be credible or significant in valuation. Therefore, in the valuation of water-works properties, it is the more important that the appraisers should weigh carefully the present character of the service furnished and the momentary adequacy or inadequacy of the rates as predicated on such service, on the needs of the community, and the existing standards of the day, if full justice is to be done.

In conclusion, the writer reiterates his statement, that he has taken issue with the author in no carping spirit of criticism, but with a recognition of the difficulty and complexity of the work of appraisal, and the conviction that engineers are under a moral obligation to do an educational work in pointedly calling attention to the fact that the going, or going concern, value, of a public service corporation's property is not an intangible value representing an unearned increment, but a very real and substantial item of cost in the property as a whole. While the difficulty may be met by placing going value, as suggested by the writer, in a middle class between physical plant and intangible values, the placing of it in the same class with franchise and other intangible elements of value, as suggested by the author, may, in the judgment of the writer, do a serious injury to corporations, in failing to give expression, in such a manner as shall be clearly within the

* Bulletin 21, Department of Commerce and Labor, U. S. Bureau of the Census.

grasp of the popular mind, to the fundamental idea of the cost of developing going value. While the writer has no personal interest in the matter, on one side or the other, having served both municipality and corporation in water-works valuations, he feels, nevertheless, that engineers can do a genuine service, alike to the public and to the public service corporation, in laying stress on the fundamental elements of cost and value, and particularly those on which rates should be predicated, in public service corporation property valuation and rating. Mr. Metcalf.

CHARLES HANSEL, M. AM. SOC. C. E.—So much has been said on the subject of valuation of public utilities that, although the speaker has thought on the subject for ten years, and has done considerable valuation of railroad properties, he finds that he is considerably confused, for the reason that the discussions seem to cover the whole field of engineering, accounting, taxation, and economics; therefore he suggests that, in order to get down to a basis of usefulness, a special committee should be appointed to take this question under consideration. Mr. Hansel.

The speaker had the honor of being associated with the Michigan Commission, as a member of the Board of Review. Professor M. E. Cooley was selected by the State of Michigan to take charge of the work of organization, and Mr. Riggs was the engineer who organized the office and field forces. Both these gentlemen were eminently successful in that very difficult work. Mr. Cooley did this Board the honor of saying that there were so many problems coming up in actually carrying out the work (aside from the theories of taxation, rate-making, accounting, and several other things, which could be found more readily in the Auditor's office than in the Engineer's), that he had asked for the appointment of this Board of Review, to sit as a Court, and to pass on the many complex questions arising from day to day; and he had the satisfaction of coming to the Board every day and saying: "Well, now here is a condition, and how will I handle it?" Of course, actually, he knew more about it than the Board, but he was kind enough to say that he would ask for the Board's opinion. That Board adjudicated all these various questions to the best of its ability, and the speaker has the satisfaction of knowing that the valuation has stood in the Federal Courts. The subjects are so fugitive and so illusive that very much depends on the point of view.

The speaker is now engaged in the actual task of trying to place a valuation on some $300 000 000 worth of property in New Jersey, involving the most important terminals in the United States.

The valuation of public service utilities is the most profound question which has ever been before the Society, and it includes a great deal which is outside of strictly engineering questions; in fact, the discussions do not throw much light on the methods which should be followed in making valuations.

Mr. Hansel. The terminology of a subject is very important; in fact, the speaker has found it so important that in his discussions with the Attorney-General of New Jersey, in reference to the Railroad Tax Law, which he has been asked to re-draft, that draft will be accompanied by a glossary, so that the meaning of certain terms used in that particular Act will be clear.

In this New Jersey work some eighty-seven engineers and assistants are employed, and for their guidance the speaker has prepared thirty-five pages of very carefully considered instructions. These instructions are accompanied by blue prints showing exactly how all field notes must be recorded, with diagrams of trusses, culverts, and the like, and all the elements of railroad construction.

The Tax Law of New Jersey states that, first, the true value of the real estate shall be ascertained; second, the true value of the tangible personal property; and the first law of 1884 stated: "and third, the value of the franchise"; but somebody discovered that there was something besides the value of the real estate, the tangible personal property, and the franchise. They did not know what it was, but there was something else; therefore, in the 1888 law they changed the third division of value to read: "the remaining property, including the franchise."

As an example of one of the difficulties of determining classification, attention is directed to the term, Real Estate, which is broadly, but seldom accurately, understood.

The Interstate Commerce Commission is the highest tribunal in the land, in the matter of railroad accounting, but it affords no help in many important elements of value; for instance, under the Interstate Commerce Commission, real estate includes only such real estate (land) as is not required for railroad purposes. All land actually used for railroad purposes is classified under "Right of Way and Station Grounds."

When the engineers on the New Jersey valuation were sent into the field, it was necessary to specify exactly what elements must be described as real estate, and what as tangible personal property. The division line had to be defined accurately for the reason that all personal property is assessed permanently to the State, while, in the case of real estate, the State receives the taxes on a strip not exceeding 100 ft. in width, and the tax on all property used for railroad purposes outside this strip reverts to the taxing district wherein it is found.

The vexatious question as to whether machinery is to be considered as real estate or personal property was settled by the New Jersey Law, which says that tangible personal property shall include all machinery; but it left unsettled the question: what is machinery? After careful consideration, real estate was divided into 74 classes, and all other tangible elements were classified as personal property. Some of the items of

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real estate are: ash-handling machinery and the like, chimneys, cisterns, conveyors, dams, locks, lock machinery, electric wiring, piping, heating, interlocking, signaling, pavements, reservoirs, shop fittings, tanks, telegraph lines, track, track scales, transfer tables, water-works, etc., etc. Generally speaking, all items of a fixed character were included in the 74 divisions of real estate.

The difficulties of determining all the elements of real estate are mentioned simply to call attention to what at first glance seems quite simple, but on close examination is found to have great complexities.

The question of useful life depreciation, direct and indirect, due to decrepitude or obsolescence, or both, is one of the illusive questions; and then comes the value of the franchise.

The valuation of railroad property in New Jersey is further complicated by the requirements of the State Tax Law, which specifies that the value of the remaining property, including the franchise, shall be determined after the "true value" of the real estate and tangible personal property have been determined.

The speaker will not attempt a discussion of franchise values, as it is a subject which requires the most profound study.

The author states that he is appalled at the speaker's misconception of the method of determining non-physical value used by Professor Adams in Michigan. The speaker is perfectly familiar with that method, and, although having the greatest respect for Professor Adams' opinions, is compelled to draw attention to two important elements of that formula which are open to objection.

Professor Adams establishes his annuity on the depreciated value, rather than on the cost, or the reproduction cost, which, in the speaker's opinion, does not determine the proper annuity or reasonable fixed charges to be deducted from net income before net surplus is established. Bonds are generally sold at a considerable discount, and represent the full cost plus this discount, consequently, the interest on bonds or fixed charges will be greater than an annuity established on cost, "reproduction cost," or "present value." Would it not more nearly establish fixed charges or annuity, to take the cost plus discount and commissions as the basis on which to apply the annuity rate?

While Professor Adams' formula establishes a larger net surplus for capitalization than the method suggested by the speaker, he in effect destroys this net surplus by charging against it all betterments chargeable to income. It is quite clear that this gives the railroad company a chance to absorb all net income into betterments, and thus wipe out all net income, in which case there would be no net surplus to capitalize, consequently, no non-physical or franchise value, and the total value established under this plan would be less than if the property had not been improved by the betterments—*reductio ad absurdum*.

Mr. Hansel.

In reference to the question of whether or not the method of valuation should be the same, regardless of the purpose to which the value is to be applied, the speaker cannot agree with the author, and believes that it is quite consistent to establish different values for different purposes.

The completion of a large public utility, planned on such a scale as to provide for the requirements of many years to come, utilizing but part of its capacity, and earning less than its operating expenses and fixed charges, with its rates of toll fixed by law, must be considered in a different way than a well-established public utility, with business forcing it to its utmost capacity, and with tolls not fixed by law. There are many important elements bearing on this consideration of value, and the purpose of the valuation should be known before attempting to establish the value.

In New Jersey the work is complicated further by the necessity of establishing the value of 122 separate railroad corporations, and the assignment of all property outside the 100-ft. strip to each of the 450 taxing districts through which the 122 corporations, with their many branches and spurs, are operating.

In order to determine the quantities and materials in the permanent way and structures, nine engineer corps were organized, each corp consisting of six men. With this force the center line of the main running track was measured, and the exact distance in each taxing district recorded. Cross-sections of the roadbed were made as often as changes in the natural surface required, and accurate measurements and notes were made of all structures; and, although in many cases the engineers were able to secure the plans of the more important steel structures, the field parties were required to obtain sufficient data to compute the tonnage in case it was impossible to get these plans.

The field parties were also instructed to note the character of the land and improvements adjoining railroad property, and record such other information as was necessary for a comprehensive understanding of the conditions attendant on the construction of a railroad in that locality.

The time allotted for the completion of the work is one year, and although this is a comparatively short period in which to introduce a premium system in field work, it was decided to inaugurate such a system as would be as nearly satisfactory as possible under the conditions. A record of each field force for each day in each month was made on profile paper, using the horizontal lines to represent the number of tracks, and the vertical lines to represent distance. Two horizontal lines were allowed for single track, four for double track, and so on. One mile was allowed for each vertical division of the paper, and, in awarding the premium, there was taken into considera-

tion, not only the extent of territory covered by each field party, but much consideration was given to the field notes, and a cash prize was awarded each month. Mr. Hansel.

The results of the organization and encouragement to the field parties are shown by the very great increase in the amount of work per man of the field parties, which was nearly 300% during the time the parties were in the field.

A great many questions hinging on interstate commerce, and involving Fundamental, State, Federal, and International Law, are embraced in the broad view of the valuation of railroad properties. The movement of rolling stock through various States, and between the United States, Canada, and Mexico, and the determination of the situs and domicile of floating equipment, are subjects which, not only require considerable knowledge of railroad operation, but involve many questions not clearly determined by the Courts.

The subject is of such great importance that steps should be taken to formulate methods of procedure, and, at the Annual Meeting of the Society, the speaker will offer a resolution requesting the appointment of a Special Committee to determine the proper methods to be used in the valuation of public utilities.

J. MARTIN SCHREIBER, M. AM. SOC. C. E.—Engineers and those generally interested in the valuation of public service properties are fortunate in having the valuable information embodied in this paper. Although there are some points on which the speaker differs with the author, the following remarks are only offered in order to bring out, from experience, some further phases of the subject, rather than as an attempt to criticize. Mr. Schreiber.

A great deal is heard about the exact cost of reproduction, also arguments in reference to the proper allowance for contingencies, probably only involving a small percentage. The speaker questions the propriety of advocating the exact cost figures. The carefully checked cost figures of reliable contractors, with first-class engineering organizations, submitting proposals on the same construction, are often found to vary from 5 to 15% from the total cost. Different organizations will sometimes be the cause of figures varying 5% or more, depending on the efficiency and experience of the corps. A clever purchasing agent will reduce an apparently precise estimate on equipment or supplies as much as 10%; on the other hand, the condition of the market may be such that the actual price paid exceeds the estimate by the same percentage. Engineers who are responsible for estimating on, and the execution of, construction projects generally add more than 10% for contingencies, as it is practically impossible to anticipate them, and a precise estimate is almost certain to fall short. It is unfortunate that it is almost impossible to sustain contingency

Mr. Schreiber.

figures on the witness stand; for that reason, probably, it would be more satisfactory to the lay mind, and to the various courts, boards, etc., which are required to pass on valuations, and do not thoroughly understand the technicalities of the situation, if engineers would drop the contingency item and modify the quantities or the unit prices.

If it is possible to estimate the exact cost of reproduction, certainly considerable variation may be expected from independent sources in computing depreciation and present values. Yet there are reputable engineers who would have one believe (assuming that they know the cost of reproduction) that by a simple field inspection they are able to compute the exact present value.

Some time ago, the speaker heard an expert testify in the interest of a certain city, for tax purposes, with reference to the value of a piece of street-railway track. He first stated the valuation for reproduction, and then the definite present value. The latter was greatly in excess of the actual value. The expert, who was an engineer of considerable standing, on cross-examination, did not know the height of rail from top of head to bottom of groove, either at the joint or any other part in its length; he did not know the exact depth of flange of the car wheels which operated over that track, the headway, or the exact weight of the cars used. He had assumed the condition of the ties, and that the track was ballasted. Finally, he was compelled to admit that his determination of the depreciation, by simply a field inspection, was a very rough approximation. Now, it is not in every case in the past that a corporation attorney, even with engineering assistance, has been able to point out unfair testimony. Many times the speaker has heard incompetent testimony admitted, on the general principle that the witness was an engineer of note, even though his record had been made in other specialities. Too much stress cannot be put on this phase of the subject, and the speaker is glad that the author has mentioned the fact that the personnel of those doing appraisal work should be of the highest order. In the past it is probable that the failure to discriminate properly in accepting incompetent testimony (not to mention prejudiced testimony) was automatic, and this is the most important reason for much of the hostility of officials of public service properties toward all forms of investigation, as the author mentions.

Company officials know that they are often compelled to employ and train specialists to furnish, within fairly accurate limits, the very information which is being sought, and naturally they are skeptical about the data presented by those who, though not intimate with the property, purport to give exact cost figures. Any one who is able to point out a consistent method whereby these exact figures may be obtained surely will obtain credit for a valuable contribution toward the solution of the complex subject of valuation.

Mr. Schreiber.

Referring to the valuation of the property of the Detroit United Railroads, mentioned in the paper, the Director of Appraisals for the city estimated that the cost of the complete appraisal of the property, which includes about 220 miles of single track, would be from $3 000 to $4 000. Approximately, $25 000 has already been spent, not including the expense sustained by the company, which furnished a large proportion of the information.

Probably correct present value estimates which include depreciation may not be even fairly approximated without intimate knowledge of the particular property, and this should embody operation, policy of management, past performance, study of historical cost (as far as the records will permit), estimated cost of construction, and actual cost of maintenance. The life of a piece of track or equipment, disregarding obsolescence and extraordinaries, generally depends on the type and details of construction, the service it has done, and the service that will be required of it. Renewals should be made when the cost of repairs reaches a certain figure, other conditions being favorable. It is a fact that able engineers, intimately acquainted with the case at issue, and employed on the same property, often have conflicting ideas in reference to the life of track or equipment, one recommending immediate renewal and another advocating longer operation.

The speaker does not intend to argue against the possibility of placing fairly accurate values on reproduction or present value, but wishes to bring out the fact that it is not as simple as the lay mind is often led to believe. Further than that, he is of the opinion that the following is essential for economical and satisfactory valuations for all concerned:

(1) There should be co-operation of the appraisers with the public service property officials, including operators, engineers, and their records.

(2) Present values should be determined by:

(*a*) Cost of reproduction,
(*b*) Mortality tables,
(*c*) Data of performance,
(*d*) Field examination.

(3) The organization for the appraisal work should be of sufficient scope, and should be allowed the time and funds which the project reasonably requires.

(4) The appraisers should be carefully selected, the personnel including men who have had wide experience in the particular class of operation; and specialists should be obtained if necessary.

Mr. Riggs states that the valuation should be the same, regardless of the principles at issue. It seems questionable to consider the fair value which involves the non-physical value in costs or tax regulations.

Mr. Schreiber.

Certainly, in the case of street railways in cities, where a percentage is levied on the gross receipts, the non-physical valuation, only representing present value, is necessary. Again, a physical present value for taxation should not include the value of paving in the street in the strip occupied by street-railway tracks. That the street-railway company often pays an arbitrary assessment tax and keeps the paving in repair, though it is in no way responsible for the wear, should be sufficient to offset any obligation for other taxes. In some States this is fixed by the Courts. The physical valuation, however, intended to be used in connection with rates, cost, or capital regulation, should include the cost of paving the railway strip. Referring further to the question of including the paving in the physical valuation of street railways, in the case of a decision of R. W. Tayler, Arbitrator, in the proceedings between the Cleveland Electric Railway Company and the City of Cleveland, on a basis of a renewal of franchises, Judge Tayler said:

"Paving represents actual money expended. It belongs to capital account, and in its depreciated form is worth all the allowance that I have given it."

Also for rate-making and the capital regulation some consideration is certainly due to obsolescence and change of art, while in taxation they should not be included.

In conclusion, the speaker is optimistic enough to believe that the problem of physical valuations will be solved satisfactorily for all concerned. Co-operation of officials of the public service properties, reliable testimony, with a better understanding by the Courts, will certainly tend to clarify the situation. Non-physical values are very difficult to determine, and their intelligent treatment will require some well-defined procedure. Mr. Riggs' valuable paper will go a great way toward producing a correct idea of the general proportion, and will, no doubt, assist in the formulation of proper methods for valuation.

Mr. Burns.

CLINTON S. BURNS, M. AM. SOC. C. E. (by letter).—The author is to be congratulated on the detailed care shown in the presentation of this subject. Perhaps few engineers who have not been called on to cope with the subject of valuation of properties, realize or appreciate the real complexity of the many varied problems encountered in work of this class. To those who are engaged directly in appraisement work, this paper will be a welcome contribution to the literature on the subject.

The author's statement that if a commission of engineers is directed to report the true cost of reproduction, depreciation, or present value of a certain property, the final figures should not differ, whether the report is to be used as a basis for reorganization, sale, rate purposes, or taxation, is open to argument. It seems proper that, if a property is appraised in order to fix a selling price to a Government or munic-

Mr. Burns.

ipality exercising its right to purchase, the final figures should be based on current prices of labor and material, because this does no injustice to either party. It is evident that if the seller secures payment for his property based on current prices, he may, if he desires, reinvest the proceeds of the sale in similar enterprises at current prices, so that thereby he secures the same benefits, whether prices are high or low.

It is equally evident that if the purchaser (the municipality) chooses to purchase the property, the right to purchase must be exercised at the particular time permitted by the franchise. If prices chance to be abnormally high at that time, the municipality is exactly on a par with what it would be if compelled to build its own plant at that particular time; while, if prices be abnormally low, the same relative situation still exists. There seems, therefore, to be no possible injustice to either party in using current prices, when the object is a sale or transfer of the property. However, in determining a proper value as a basis of rates, another factor must be considered. It is inexpedient and against public policy to make frequent changes in the rate charged for such commodities as water, gas, or electric current. Theoretically, the rate could be fixed each year, based on an annual valuation of the property, thus permitting a high rate one year and perhaps an abnormally low rate another year; but, practically, this is impossible, for, aside from the inconvenience of such a cumbersome system, no community is well enough informed as individuals to comprehend any reason whatever for ever raising rates. Raising rates is invariably accompanied by a wave of indignation. However, it is apparent that a series of rates based on an annual current price valuation of the property would average exactly the same, during a term of years, as though the property were valued once for all on the basis of the average prices of labor and material for the same term of years, and the rate based on the one valuation thus determined.

If the object of the valuation is to afford data for taxation, the same argument applies as in a case of fixing rates. It thus seems proper that the object of the appraisement should be taken into consideration before it is determined whether to use average prices, or current prices, of material and labor; and, if this is correct logic, the final figures must differ according to the object in view; but, having determined the proper unit prices to be used throughout any appraisement as being the most equitable for the object in view, then, as the author well says, the appraiser must not allow personal prejudices or fancied conditions to influence his course. Above all, an appraiser must not be afraid of his client. He must not allow his personal judgment to be swerved by the latter's desires. It perhaps seldom if ever occurs that an appraiser, representing a municipality, or State, is subjected to this unconscious influence, inasmuch as his employer

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is merely a temporary public official, and consequently he has no client to fear. He goes into the work with a full knowledge that his employer knows little or nothing of the subject, and his only desire is to reach results which will be unquestionably fair to both parties.

On the other hand, the appraiser who is chosen by the owner of a plant takes hold of the work with a feeling that he is expected to report a value as favorable as possible to his client, and this feeling is reflected in the report, regardless of how sincerely or conscientiously he tries to avoid it.

One of the most intricate and yet interesting problems in appraisement work is the computation of the "going value," or "business value" which should be allowed in addition to the physical value.

In considering a competitive enterprise, such as a railway serving a community in competition with another independent railway, this problem must be treated in a different way than in a non-competitive business, such as a water-works, gas-works, electric plant, street railway, or similar enterprise operating under the protection of an exclusive franchise, or under natural conditions equivalent to an exclusive privilege.

In considering competitive enterprises, it is manifest that a railway operating under conditions more advantageous than its competitor possesses an intangible value equal to the measure of that advantage. It is not clear, however, whether it is more proper to say that the railway possessing the advantage has a positive going value, or whether the less fortunate one has a negative going value. Using the rule formulated by the author, being that of Professor Adams, with some modifications, it is evident that many properties would show negative going values; but, as pointed out by the author, the Courts hold that public service corporations are entitled to earn:

(*a*) Operating expenses;
(*b*) Expenses of maintenance and running repair;
(*c*) Taxes;
(*d*) A sinking fund to cover depreciation and obsolescence;
(*e*) A reasonable profit on the fair value of the property.

It is improbable that a reasonable profit on the fair value of the property could be construed to mean less than the interest or revenue from a like amount of Government bonds or other non-taxable securities.

This ruling of the Courts fixes the rates at such a figure as to preclude the possibility of a deficit; from which it must follow that a negative going value cannot be created by a compulsory reduction in rates, for such action would be confiscation of property to the extent of the negative intangible value thus created; that is to say, if the Courts are right in the above ruling, then all intangible or going values

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are positive, and must be determined by using the most unfavorably situated railway as the basis of computation in determining the question of reasonableness of rates; and the rates in turn must be reasonable and proper before they can be applied to determine the intangible value. This raises an interesting and far-reaching query. Assume that a negative going value is the result of real competition between two roads such that the "fair value" of the less fortunate competitor is 20% less than its physical value.

If rates are based on this valuation, are they really fair rates? For, suppose the rates had always been maintained at a point where the less fortunate road could just support its physical valuation. Clearly, no rate could then be enforced which would compel it to operate for less than a reasonable profit on the fair value of its property, and the fair value under this assumption is 25% greater than before, due to no effort of its own, but simply to the fact that its competitor has not cut rates, and has thereby preserved the original "fair value" of the less fortunate road, and at the same time increased its own positive going value by an equal amount.

In view of this analysis it is doubtful if it is ever proper to consider the existence of negative intangible values, although it is true that the commercial value does fluctuate, and may be less than the physical value, due to rates which are too low, perhaps, or due to other temporary causes.

The method quoted from Mr. Alvord for determining going value applies to non-competitive enterprises only, as was stated by Mr. Alvord in his paper before the American Water-Works Association. This method is open to the criticism that the forecast of the business of the older works, and of the new hypothetical works as well, is reduced to a monetary value, based on the present rates, regardless of whether or not such rates are reasonable. Rates are subject to legislative control in many States, and there is absolutely no assurance that any other State may not adopt legislation at any time permitting regulatory ordinances to be enforced. Therefore, any forecast of the value of future business must be based on reasonable rates, for otherwise it is merely an unwarranted estimate based on a fond hope.

Taking into consideration the fact that rates must be reasonable, either by virtue of present laws or laws which may become effective at any time, perhaps in the immediate future, going value may well be defined as the present worth of the amount by which the anticipated profits of a going plant, operating at reasonable rates, exceed the present worth of the anticipated profits of a similar hypothetical starting plant, operating at those same rates. With this conception of going value, it is impossible for a non-competitive property to have a negative going value, and every operating plant has a positive going value, even though operating at a loss.

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The whole problem hinges on the question of "what is the reasonable rate or proper return," and this should be determined in the aggregate as the starting point. The Courts have persistently dodged the issue, and properly so, whenever that question has arisen, leaving it for consideration in each particular case, depending on the stability of the business, the hazard involved, and various other local factors.

It may safely be conceded that this fair profit is something in excess of the return from Government bonds, and for the purpose of this discussion it matters not what figure is assumed as the fair profit—whether 5, 6, or 10%, or what-not—the theory is the same in any case. This is perhaps best explained by a practical illustration:

Take, for example, a water-works system, the physical present value of which has been determined by the method of reproduction to be $1 000 000, and denote the going value by the unknown quantity, x; suppose, further, that 6% is considered a reasonable return on the "fair value"—not yet determined, the "fair value" being $1 000 000 plus the going value, x. Therefore, the rates must be such as to produce in the aggregate an amount equal to the operating expenses, maintenance, taxes, sinking fund, and depreciation, and still have a profit of 6% on the fair value of the property. The anticipated profits of the going plant, therefore, are exactly 6% of ($1 000 000 + x) = $60 000 + $\frac{6\,x}{100}$ per annum. The anticipated profits of the hypothetical starting plant will be negative at the start, and gradually increase, finally reaching a maximum of $60 000 + $\frac{6\,x}{100}$ per annum.

It must be remembered that, in estimating the operating expense and income of the starting plant, as well as the going plant, the figures must be confined rigidly to the plant as it is found at the date of valuation, and in no case should any account be taken of income or operating expenses due to probable future extensions of the distribution system. Many appraisers overlook this point, and predicate the anticipated profits of the going plant on the past growth of the income account, forgetting that a considerable portion of this growth is due to extensions into new territory, and not to any material increase in revenue from the territory already served. To include income from new territory in the forecast of income is just as fatal an error as to include the anticipated expenditure of new capital in the present physical valuation. Either of these procedures is really an estimate or appraisement of some other plant, rather than the one actually under consideration.

To complete the numerical illustration, suppose it is determined that the time required to construct the hypothetical starting plant is 3 years; that a portion of the plant is put into operation at the end of the second year, taking over fire-hydrant rental equivalent to $20 000;

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that the revenue from private sources aggregates $20 000 during the last year of construction; that the expenses of operation, maintenance, taxes, and depreciation amount to $30 000 during this year. After the time of completion of the plant has elapsed, it has the total credit for fire-hydrant rental, and it is assumed that the revenue from private sources and the cost of operation, maintenance, taxes, and depreciation increase as shown in Table 14, which illustrates the method of computing the going value, and gives the resulting value for the case just stated.

Therefore, $171\,005 + 0.2597\,x = x$; hence, $x = \$231\,000$. This result is based on the assumption that the starting plant earned no interest during the construction period. If an allowance for lost interest during construction has been made and added to the capital account already being included in the physical appraisement of $1 000 000, then this must be charged back against the going value found above. This is clearly evident, because the calculations to determine going value date from the beginning of the construction period, and the lost interest during construction, therefore, is provided for in the result. Most appraisers allow an item for lost interest amounting to the legal rate of interest running for half the construction period, which, in the illustration under discussion, would be $90 000; deducting this sum, if previously included, gives $141 000 as the going value.

There seems to be no good reason for allowing lost interest during construction as an item in the physical valuation of a property, any more than for allowing all of the lost interest, up to the time when the property begins to yield a return equal to the rate of interest. It is one of the problems in finance, and is much better treated as an element in the going value, as shown in the above illustration.

One of the most difficult factors on which to agree in computations of this nature is the element of time required for the hypothetical starting plant to acquire the business. Were it not for this uncertainty, going value could be computed with mathematical precision by the method suggested.

In determining the physical valuation on the basis of cost of reproduction, such items as cost of taking up and replacing street paving over the pipe lines, cost incurred by reason of sewers and drains encountered, interference due to electric wires and conduits, interference of traffic, and other metropolitan conditions which add greatly to the cost of construction, must be allowed. Wherever such metropolitan conditions exist, there must also be present a corresponding necessity for the use of water under pressure. People use water because of necessity or convenience, and not on account of any feeling of obligation or loyalty to the water company.

If highly developed metropolitan conditions are present, new busi-

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TABLE 14.—COMPUTATION OF GOING CONCERN VALUE, BASED ON REASONABLE RATES.

Year, dating from beginning of construction.		Legitimate profits of the going plant.	Hydrant rental taken over by starting plant.	Domestic revenue of starting plant.	Interest on the starting plant.	Operation, maintenance, taxes, and depreciation on starting plant.	Total difference in anticipated profits of the two plants.	Present worth factor.	Present worth of the excess of anticipated profits of the going plant.
Construction period.	1st	$60 000 + 0.06x	0	.....	If the physical valuation contains an item for lost interest during construction, the same amount must be credited to the starting plant as interest earned.	0	$60 000 + 0.06x	95.2	$57 120 + 0.0571x
	2d	60 000 + 0.06x	0	.....		0	60 000 + 0.06x	90.7	54 420 + 0.0544x
	3d	60 000 + 0.06x	$20 000	$20 000		$30 000	50 000 + 0.06x	86.4	43 200 + 0.0518x
Business development period.	4th	60 000 + 0.06x	40 000	55 000		50 000	15 000 + 0.06x	82.3	12 345 + 0.0494x
	5th	60 000 + 0.06x	40 000	80 000		65 000	5 000 + 0.06x	78.4	3 920 + 0.0470x
	6th	60 000 + 0.06x	40 000	90 000 + 0.06x		70 000	0	74.7	... .

Total going value = 171 005 + 0.2597x
x = $231 000

ness will be acquired in the hypothetical starting plant much more rapidly than where such conditions are yet to be developed. For this reason the problem cannot be based on the early growth of the same plant, and, there being no exact duplicate of conditions in existence elsewhere, the estimate of time required for the business development period is purely speculative, and must be assumed with great care and judgment, else injustice may be done to one party or the other in the resulting going value. Mr. Burns.

It is interesting to note that, in the Michigan appraisal, the allowance of a percentage for contingencies was bitterly contested by the railroads as improper. Probably every appraiser who has been connected with rate cases has seen this same item strenuously insisted on by the corporations.

The author's query: should a corporation which is compelled to abandon appliances while yet serviceable, in response to public clamor, be allowed any item of value in the appraisal on account of such appliances, seems to be best answered in the negative. If the appraisal is for the basis of making rates, the corporation is fully compensated by the fact that its depreciation account provides for all abandoned machinery, and the average past depreciation is usually considered a fair criterion of the future. If the appraisal is for purposes of taxation, it would seem improper to levy tax on abandoned or rejected machinery or equipment. If the appraisal is to determine the present value of a property for sale under condemnation proceedings, it is likewise difficult to conceive any reason for allowing any present value on account of property abandoned or rejected, and, indeed, if such abandoned material had any value at the time of its removal, it is more than likely that such value was converted into cash at that time.

The statement that no appraiser would be justified in placing a going concern value on a property 3 years old, or 10 years old, unless the net earnings were such as to indicate that the property had a commercial value in excess of the physical property, is questionable. "Commercial value" is not exactly synonymous with "going concern value," for, as usually considered, the term "going concern value" represents the difference between a dead structure and a live one. A property might be compelled to operate temporarily at rates insufficient to return the legal rate of interest on the physical value of the property, and while this condition continued, its commercial value would be less than its physical value, and yet this same property is worth more while running than if operation ceased and the business was allowed to die.

HALBERT P. GILLETTE, M. AM. SOC. C. E. (by letter).—In common with others who have written on the subject of appraisals, the author omits consideration of one of the most important elements of the cost of producing the property of a public service corporation, namely, the development expense. Mr. Gillette.

Mr. Gillette.

Development expense is the deficit in "fair return" on the investment during the early years of operation, while the business is being developed to a point that will yield a "fair return" on the investment. Unless this development expense is charged to the capital account as fast as it occurs each year, it should draw compound interest up to the end of the development period. Development expense might be regarded as a part of the non-physical value of a plant, and a few years ago the writer so regarded it. Latterly, however, he has come to see that it does not differ one iota in principle from "interest during construction," and, therefore, is properly a part of the cost of production or of reproduction of the property. During the construction period, interest on the investment is charged, and properly so, as a part of the physical cost. Does this interest cease the day after operation begins? Not a whit. The owners of the property are entitled to a fair interest—a "fair return"—on their money, from the day it is invested. At first they receive it in the form of "interest during construction," which is charged to capital account. After operation begins they must either be allowed to earn more than a "fair return" during the fat years following the development period, or the deficit below a fair return incurred during the development period must be treated exactly like "interest during construction" and added to the capital account. If public service corporation managers have chosen the first of these two methods, it does not relieve the appraiser of the duty of adopting the second method; for the object of appraisals for rate-making purposes is to limit capital to a "fair return" on the investment. In brief, if there are to be no "fat years," then every "lean year" must be credited with its deficit as fast as it occurs.

This, the writer concedes, is a radical departure from such precedent as already exists, but we must not overlook the fact that we of to-day are establishing the precedents for appraisals in the future. The whole matter of valuations for rate-making purposes is still in a nebulous form, as far as the public, and indeed, as far as the Courts, are concerned. In the end it will devolve upon engineers to establish logical methods of appraisal. To do so, they must be able to look on the problem both as engineers and as jurists. Up to the present, however, this broadness of vision has not characterized most engineering appraisers, nor is it to be wondered at when the Courts themselves are in a maze.

A great deal has been heard lately about "going concern value." Ultimately, the Courts will hold that, as far as rate-making is concerned, there is no such thing as "going concern value" in the present meaning of the term. "Going concern value," in the final analysis, consists of two elements: First, development expense (as previously defined), and, second, capitalized surplus earnings. Surplus earnings are ascertained by deducting from net earnings both taxes and a low

rate of interest on the investment, equivalent to interest on bonds. Many factors may affect surplus earnings; but, that "going concern value" consists largely of capitalized surplus earnings, cannot be denied. What are surplus earnings? The public replies that they are mainly the result of extortionate charges. This is doubtless correct in many cases; hence, any investigation of costs which has for its object rate-making must inevitably lead to repudiation of that part of "going concern value" which is based on surplus earnings, if the surplus is at all large. In a word, we reason in a circle if we capitalize surplus earnings, calling the result "going concern value," and then undertake to use "going concern value" as one of the factors in judging the fairness of rates. To express the problem mathematically, we cannot solve for a variable when the variable is allowed to exist on both sides of the equation. Yet that is precisely what some rate-making bodies are trying to do, and it is precisely what the Courts have often attempted to do. Mr. Gillette.

To escape this confusion there is but one possible step, and that is to eliminate "going concern value" entirely. We must first determine the element of cost, which the writer terms development expense, and we must regard this item as a part of the cost of reproduction. We must next cease to consider small rates of interest as being a "fair return" on this cost of reproduction. When first-class mortgages draw 5%, it is folly to talk of 6% as being a "fair return" on capital invested in a business enterprise, especially when this 6% is figured on the actual cost of reproduction of the property. It may be that 7% is an ample "fair return" in some cases, but in others 10% will be found none too much, considering the small size of the business and the risks involved.

The writer will not at this time discuss methods of determining how a "fair return" should be estimated, but, in general, the process should be as follows: From the gross earnings deduct the operating expenses and taxes to obtain the net earnings. From the net earnings deduct a small rate of interest (equivalent to interest on bonds) on the cost of reproduction. The remainder is profit, and should be expressed as a percentage of the gross earnings. This percentage of profit can then be compared with similar percentages made by merchants, manufacturers, farmers, and other capitalists, and then it can be determined logically by comparison whether or not the profit made by a public service corporation is "fair." We must adopt this method of attacking the problem or we shall inevitably drive capital away from railway and other fields of public enterprise.

The writer estimates roughly that a profit of 10% on gross earnings, as above deduced, is about the same as a direct return of 7% on the cost of reproducing the average steam railway.

In a recent appraisal of a street-railway system, the writer determined the actual development expense of the property, deducing

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it from the accounting records. It was an astonishingly high sum, even assuming only 7% on the cost of reproduction as being a "fair return." During his appraisal of all the railways in the State of Washington, for the Railroad Commission, the writer made a similar study of development expense, but this was not included in his estimate of the cost of reproduction, as it was then regarded as being a part of the "going concern value" and he was not commissioned to ascertain the "going concern value" of the railways. Not a single railway, as far as he knows, has ever presented to a State Railway Commission, or to the Interstate Commerce Commission, an estimate of its development expense along the lines indicated. Instead, the railway companies have talked in general terms of long construction periods—often claiming 20 years or more—and of great expense incurred in building up the business, and of franchise value, and of a score or more of non-provable costs. The consequence is that they have frequently lost entirely the one great item that they are clearly entitled to, namely development expense, which is an item which can be absolutely proved from their accounting records, and, therefore, rests not on the "hot air" testimony of experts, but on facts that are incontrovertible. In like manner, other public service corporations have often signally failed to prove the full worth of their properties, because their claims for "going concern value" have been ignored entirely. When a franchise expires, the "going concern value" is usually looked on by the public as worthless, nor is this view to be wondered at.

Mr. Riggs proposes adding to the physical value a minus "going concern value," and he is logical in doing so, if it is conceded that values for rate-making rest on profits; but this the writer does not concede for an instant. Values for rate-making cannot rest on the very thing that it is aimed to regulate, to wit, the rates charged. Until engineers and public service commissions and Courts free themselves from this confusion of cause and effect, there can be no rational theory of rate-making.

Values for rate-making must rest primarily either on the actual costs of the production of a property or on estimated costs of reproduction, including therein both interest charges during construction and the sequel thereto—development expense.

Of almost as great moment as the item of development expense is the question of depreciation. The author, in common with most engineers, holds that depreciation should be deducted. This is a consequence of regarding a public service plant as if it were a machine bought in a second-hand store. A public service plant is a device which is intended to perform a given service forever. It is true that its parts are subject to wear, and must be renewed from time to time; but the plant as a whole is everlasting, or practically so. Managers of public service corporations, perceiving this fundamental truth, have rarely established sinking funds

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for the redemption of any considerable part of the plant. In a great railway system the renewal of a freight car is not a proportionately larger item of expense than is the renewal of a tooth in a steam shovel bucket owned by a contractor. This fact, coupled with the permanence of the railway plant as a whole, has led railway owners to make no provision for a return of the money lost in depreciation. Railway ties in a large railway system inevitably reach a condition such that their average age is exactly half the life of the average tie. Shall a sinking fund be provided for ties? If not, where does logic place a line of demarcation? When does an element of the railway plant attain a condition of sufficient importance to warrant "writing off" some of its value from the capital account? The facts are that railway managers have not "written off" anything worthy of mention for depreciation, and, in the writer's opinion, they have been perfectly logical. Consequently, the operating expenses have been much less than they would have been during the early years, had a sum been placed annually in a sinking fund. Therefore, the development expense, as deduced from the accounting records, is less than it would be if a sinking fund were provided; and the amount of this difference is precisely the amount of the depreciation. In other words, if depreciation is to be deducted from the cost of reproduction, it must be added to the development expense ascertained from the accounting records; so that, in the final analysis, depreciation should be ignored entirely in any appraisal of a public service corporation where the object is either rate-making or purchase of the corporation by the public. One qualification to this statement is needed, however, and that is that the depreciation shall not have gone far enough to result in an average age of plant less than half the life of the plant—that being the ultimate normal operating condition.

Engineers have a duty to perform, in making an appraisal of the sort under consideration, which is judicial in its character and should not savor in the least of the pawnshop. The engineer engaged by a public service commission should not for an instant make it his object to "beat down the price," no matter by what far-fetched theory he may effect the result. Nor are engineers inclined to do this, except when they regard themselves merely as agents of the public by whom they are employed. Unfortunately, many appraisers have as yet failed to realize that there is a vital distinction between the dealings that should exist in public affairs and those that actually exist in private matters involving the purchase and sale of property. In the latter case, the buyer usually takes every possible advantage of the helplessness of the seller. Is the seller ignorant? See that he remains so. Is the seller hard-pushed for money? Grind down the price accordingly. Does the seller offer goods which are a bit shop-worn? Dwell on that fact, to the exclusion of all else. Such are the tradesman's arts, and such,

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the writer fears, have been the arts of some appraisers of public service property.

The writer believes that, under one form of agreement or another, nearly every kind of public service can be more economically and better performed by a public service corporation than by the public itself through employees directly hired. But if America is not to pass speedily into Government ownership and operation of all public utilities, there must be a pronounced change of attitude on the part of the public toward capital now invested in public service corporations. Even as engineers, we are apt to be unconsciously influenced in our attitude toward public service corporations, not only because of the present public attitude, but because we are often put to great inconvenience by the ill-considered resistance of the corporations whose property we are called on to appraise for the public. Our duty plainly consists, first, in regarding a public service corporation as a public agent, and, second, in allotting such values that this public agent will receive a full and fair return for every dollar judiciously and honestly spent in building and developing its property. In carrying out this plan, the writer finds it wise to study the entire financial history of a corporation, going carefully through both the construction accounts and the operating accounts from the beginning.

The desirability of analyzing the actual costs of construction, betterment, and operation of public service corporations, preparatory to estimating the cost of reproduction, cannot be too strongly urged upon appraisers. Unfortunately, many corporations refuse access to their records, or claim that the records are too incomplete to be of value. However, when they realize that from those very records can be deduced one of the largest items of cost of reproduction, namely, the item of development expense, they are certain to show as much willingness as they now show aversion to disclosing their records.

The writer has recently completed an appraisal of a street railway system, the managers of which placed at his disposal the entire accounting and engineering records. From these the development expense was deduced, and forms an item which can be demonstrated in Court, if need be, instead of being the subject of unsupported "expert testimony." As far as the writer knows, this is the first time that a street railway corporation has voluntarily opened all its books for use in an appraisal which may be made public. May it not be one of the harbingers of a far-sighted action on the part of public service corporations, which will result eventually in eliminating entirely the hostile attitude of the public toward its accredited agents?

Reverting again, and finally, to the question of development expense, it will be seen, after study, that the method of deducing it from the accounting records provides for every possible item. The cost of advertising, the cost of colonization, and canvassing by agents engaged

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in building up the business tributary to the corporation, the cost of developing an efficient business organization and an efficient plant—every possible item of developing the business finds accurate record in the development expense deduced from the accounting records as outlined. This may not be apparent at first glance, but a little consideration proves it to be so. If, for example, $20 000 has been spent annually for ten years in advertising to secure business, the operating expenses have been increased exactly $20 000 for each of the ten years. Consequently, the annual deficit below a "fair return" on the investment has been made $20 000 greater each year than it would have been had no expense for advertising been incurred. In other words, the deficit below a "fair return," which is the development expense, shows automatically the amount spent for every such item as advertising. The writer regards this automatic register of development expenses as being one of the most important features of his method for determining such expense. It removes the entire problem from the realm of guesswork and expert testimony, and makes it a problem in engineering economics. It involves no question as to whether or not the existing rates charged for freight, or for any other service, are fair.

Mr. A. L. Adams.

ARTHUR L. ADAMS, M. AM. SOC. C. E. (by letter).—This paper, in spirit, diction, and contents, is a masterly presentation of the best thought and argument, by engineer specialists and the higher Courts, concerning this difficult subject—a presentation which only one intimately associated with the question for years, as has been the author, could hope to make. It is of special interest, too, because it deals fundamentally with the Michigan railroad valuation, now ten years old, and deservedly considered somewhat ancient in the evolution of what may be termed the logic of valuation methods. The frank acknowledgment of the now apparent deficiencies or errors of that work, notably in the defective method and resulting under-valuation of real estate, as well as the upholding of that which still appears to the author to be sound in principle, are excellent manifestations of the constructive and judicial spirit so necessary to the making of any substantial contribution to the art.

Unanimity of opinion in matters of detail, even among those specializing in this line of practice, cannot be expected, especially in a general discussion. Details must receive their emphasis from local coloring and local conditions. Making allowance for these local conditions in Michigan and other contiguous States—notably conditions of population and flat topography—and remembering that the basis of the paper is a railroad valuation for purposes of taxation, and not a water-works appraisal for annual rate-fixing in a semi-arid region of rapid development, or some other widely differing utility, it seems to the writer that the author has been singularly fortunate in giving expression to views with which specialists will for the most part agree.

Mr. A. L. Adams.

The limitations of the logical application of the methods suggested, however, are not sufficiently defined. Early in the paper an effort is made to avoid the necessity for this, and to simplify the treatment by limiting the scope of the paper, in the following language:

"This paper is confined to a discussion of the methods which should be used in arriving at a correct figure of cost of reproduction and depreciation—it does not take up questions involving the propriety of those figures when reached. The propriety or legality of using such figures as a basis for an assessed valuation, as a basis for rate-making, * * * will be conceded no place in this paper."

Such a restriction, however, seems to the writer to leave the subject much confused. It is impossible to judge of the propriety or soundness of a method of valuation while ignoring its purpose and failing to point out the limitations of its logical application. To confine discussion to a consideration only of cost of duplication and depreciation of physical properties is presumably an attempt to avoid the difficulties incident to the application of such results to specific purposes, and is in line with the frequent argument of some attorneys in litigated valuations, that the engineer must not encroach on the province of the Court by having, much less expressing, any idea relative to the application of his figures to the final solution.

With this doctrine the writer has no sympathy. The engineer is essentially an economist, and no one is more fully qualified to aid, either directly or as an adviser to the Court, in the final determination of value for specific purposes, provided he is trained in the construction, operation, and valuation of such properties as are under consideration. To accept any less responsibility than this is to become party to inferior measures leading to popular misconception, and is justified only as a practicable first step toward the final realization and acceptance of the larger duty.

All suggested methods of valuation should be subjected to close logical analysis, with a view to their purpose. The unsuitability of the method used in the Michigan appraisal to many classes of appraisals is apparent, and can be readily indicated. Much space is given to justifying the appraisal of all so-called non-physical elements by the capitalization of the residue of net earnings after allowing interest on the investment in the physical properties. This the author refers to as Professor Adams' method. The addition of the physical to the non-physical values, as thus determined, is supposed to give the value of the property as a whole. It is evident that it gives, by indirection, the same total valuation as would be obtained by the direct capitalization of net earnings without any determination of physical values, *per se,* and, as a method, is therefore not what it purports to be. Since value, by this method, is in reality dependent on earnings, it follows that where rates are fixed by governmental authority, with the property

value as the base, as is done annually in California in cases of privately owned water and lighting plants, the method suggested is without logical application, and the property values of such corporations must be determined and justified on other or modified grounds. Hence the necessity for dealing with such elements as so-called "going concern," franchise, and other possible assets, each independently, as is usually done in water-works appraisals, instead of collectively, as in the Michigan appraisal. Mr. A. L. Adams.

It should be made clear, therefore, that the method used in this railroad appraisal, for the determination of non-physical values, simply reduces the whole to one of capitalization of net earnings, and presupposes no governmental regulation of rates with the value of the property as the base; and, unmodified, has a comparatively narrow range of application.

The author seems to see difficulty ahead in dealing with rate-making by this method, for he says, near the close of his paper: "There are many intricate problems in connection with a valuation for rate-making or taxation which really belong to these undertakings, not to valuation," but, in stating some of these difficulties, he does not point out the impropriety of determining value by capitalizing that (earnings) which it may be the object of the valuation to determine and fix.

Regulation of rates by governmental authority, which means their limitation to that which is reasonable and just, will probably in the future be the purpose in the making of most valuations of the property of public service corporations, and no methods or rules for the making of appraisals can be considered as being at all complete or fairly comprehensive which do not meet the logic of such an end.

If capitalization of net earnings is to determine railroad values for rate-fixing, whatever the process, it must presuppose a fair and equitable rate, thus following the rate, instead of the rate following the property value. This is but a shifting of the difficulty; for, what constitutes a fair and just rate, irrespective of the value of the property used, is at least as difficult of determination as is the property value, irrespective of its earnings. Valuations, to be useful, must have their purposes carefully predetermined, that the right application of principles may be made.

Perhaps nowhere more than in California has thought been directed along this line, for the organic law of the State for thirty years has required the annual fixing of rates for water and light companies by public official bodies, and many important cases involving rates and valuations of large properties, chiefly in later years, have been tried. Unfortunately, the most important and best tried of these have not yet reached the United States Supreme Court. The result, thus far, is too long a story to be told now, but it may be said that capitalization of

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earnings in any form is not regarded as a logical basis of value under such conditions. Franchises, as they exist here, are not regarded as having value, unless from unusual circumstances. "Going concern" value is recognized, but its money measure is sought through other channels than present net earnings.

The author's emphasis on the necessity for eliminating the personal equation, as far as possible, is commendable, but a large exercise of discretionary judgment is inseparable from the process of appraisal. The fullest investigation of all pertinent facts should be made. Too much must not be expected from rules and formulas. They are education only. Governing principles must be understood, and subsequent procedure the writer cannot better express than in the words substantially as used on a former occasion:* Having considered the various factors likely to influence the value of any property under consideration, and having summarized the results, it will remain to determine the varying degrees of importance and weight to attach to each, and to decide, in view of all the attendant circumstances, what the amount is on which the company is entitled to receive a suitable return. This final solution can never be reduced to a mathematical formula applicable to all cases. The inquiry will have established approximate limitations, both as to maximum and minimum, but there will then usually be found remaining quite a wide intervening field for the exercise of discretionary judgment.

That the final result will depend to some extent on the personal equation, does not of necessity detract from its worth. It only shows the greatness of the problem, which requires for its solution the exercise of faculties higher than the application of mere formulas and mere routine, faculties which are rooted in laborious thought, in ripe experience, in moral worth.

A word concerning the use of experts on work of this class: Most valuations grow out of or grow into cases at law. Under the prevailing order, the litigants secure the services of the necessary expert appraisers, who, in the course of examination, are subjected to processes usually much better calculated to magnify than to harmonize differences, and to cloud rather than to clarify issues, to the detriment of the record, the confusion of the Court, and the attempted discredit of the witnesses and their profession. Self-defense is calculated to lead witnesses into undue reliance on rules and mathematical formulas, as direct means of obtaining the desired result, instead of aids for the final exercise of a right judgment as to the real value of the property for the purpose intended, simply because it is easier in dealing with attorneys to justify mere mathematical processes than to support opinion resting on considerations of a general character, not always

* "The Principles Governing the Valuation for Rate-Fixing Purposes of Water-Works Under Private Ownership." By Arthur L. Adams. *Journal*, Assoc. of Eng. Societies, Vol. XXXVI, No. 2.

readily measurable in figures. This tendency leads also to under-valuations. A change in the process of Court procedure relative to such expert evidence is needed, and the influence of the Profession, both individually and collectively, might be used to secure the appointment of such witnesses at the instance of the Court, instead of the litigants, to the great advantage, both of society and of those more immediately concerned. Mr. A. L. Adams.

C. D. PURDON, M. AM. SOC. C. E. (by letter).—A comparison of some of the more important items in the Minnesota valuation may be of interest. In the "Cost of Construction of Roadbed and Track," the principal items are: Mr. Purdon.

Land	25.46%
Clearing and grading	21.49%
Rails	12.72%
Bridges	7.01%
Ties	6.72%

These five items amount to 73.40% of the total cost, and "Adaptation and Solidification of Roadbed" to 4.53%, the other twenty-three items amounting to 22.07 per cent.

The estimated value of "Adaptation and Solidification of Roadbed" ranges from $543 to $1 542.80 per mile, averaging $1 231.92, which includes 4½% for engineering. If engineering is omitted, the average for all roads is $1 124.95, and for "Carrying Roads"* $1 128.16.

The "multiplier" for cost of right of way was ascertained from the market value of land in the vicinity, as shown by late transfers, and the prices paid for right of way at about the same time; this cost ranged from 195 to 891% of the market value. Taking "all roads," the cost of land for terminals was 71.05% of the total cost of land for all purposes, but only 3.78% of the quantity.

A. MORDECAI, M. AM. SOC. C. E. (by letter).—Mr. Riggs has done a valuable service in preparing this very able and painstaking paper, as the subject of the proper value of Public Service Corporation property is one but lately demanding attention. When the country was undeveloped, and the railroad companies struggling for existence, and often ahead of the needs of the people, no criticism was made; but, during the last few years, securities have increased so largely, the increased issue often being manipulated so as to accrue to the benefit of a few individuals in place of the great mass of original security holders, rates have been made and defended on the plea that the increase was necessary to pay a fair interest on the capital invested, and increases in assessments for taxes were fought and criticized to such an extent by the companies that the public seems to think it Mr. Mordecai.

*The Minnesota Commission classified all roads as "Carrying Roads" or "Switching Roads," the latter being mostly Union Depots.

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absolutely necessary to have some investigating and regulating power. It argues that the history of the past shows that we cannot depend on the officials themselves, not from any desire to be dishonest or unfair, but merely that they cannot reach the proper point of view. After years of struggling, they cannot see the justice of being obliged to show their books or have their incomes disturbed, while they see a neighboring factory, owned by a like chartered company protected by patents and copyrights, greatly enlarged, and the company paying a very handsome return on an ever-increasing capital, without investigation of any kind.

No one supposes that any body of legislators or a committee selected from one should understand the situation better than the managers themselves, but the public, forced to look somewhere, demands that its representatives try to regulate these matters and see that no abuses occur, fully aware that the machinery is not perfect. It asks:

As to Capital: that the company can show proper value for the securities issued, and, if an increase is made, the sum obtained should be used for the betterment of the property;

As to Rates: the Courts have said that what the company is entitled to ask is a fair return on the value of that which it uses for the public convenience;

As to Taxes: what is the true value of the property of the company, treating it with absolute equality, as compared with that of other taxpayers?

It is to determine what these values are that the Engineer among others has been called on. The literature on the subject is increasing, and there are some decisions of the Courts which help, but there are yet perplexing and intricate questions to be determined; not to be answered by captious criticism and indignant retort, but by an honest effort to arrive at some common ground of fairness to both State and Corporation; for, after all, the Corporation is a part of the State, a great distributor of money, a large taxpayer, its stockholders men of worth and capacity, and there should be no desire to penalize it or interfere with its legitimate prosperity. The Corporation is surely dependent on the State and the good will of the people for its welfare. Mistakes have been made, no doubt, just because this common ground has not been reached, and the writer thinks that it is largely within the province of the Engineer to establish it.

In arriving at either of these values, the chief tangible asset is the value of the physical property. This can be determined with a great degree of accuracy, and though by no means alone representing any of the values, it seems to be indispensable as a basis and starting point. The balance sheets of the Corporation commence with a statement of the cost of road, plant, etc., and must be checked to permit

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correct deductions from the results of operation shown in them; and, for purposes of taxation, they would seem to be particularly reliable.

The Engineer called on to make such a valuation for whatever purpose should, under like conditions, value each item the same for all, but it does not follow that every item, including the percentages added, should appear in the total valuation for all purposes. There are legitimate charges in valuations made to determine capital which should not appear in one made for assessment for taxes. Unit prices should not change, but the purpose for which the valuation is made should properly be considered in arriving at the final figure.

To or from this valuation, especially if made to determine proper capital, there must be added or subtracted certain values for intangible property, often found by a study of the income account of the Corporation. This makes the official ask: Why make a valuation of the physical property at all if your final result depends on the income? Because it is one item which cannot be manipulated; it does not change materially from year to year; it is not dependent on rates or income; it forms a very large item in the assets of the Corporation; and it is a sound basis on which to stand.

For the purpose of determining the proper amount of securities, the cost of reproduction at present prices would seem to be the value sought; whereas, for taxation purposes, or to determine a proper selling price, the present value is what is required, allowance being made for depreciation. A railroad, for instance, might be considered as an instrument for transporting passengers and freight, and, though the ties are not new, the rails worn, and the locomotives of an old type, they do their work just as safely and expeditiously, and, if no account is to be taken of the cost of maintenance, the road might be considered to be worth as much as if new.

The officials of the Corporation are generally perfectly willing to give any facts or to furnish access to any records they may have, but are not willing to state their opinions as to prices, depreciation, etc. The Engineer is making the valuation, not they; and they reserve the right to criticize, at the proper time, both the results and the conclusions drawn from them. The Engineer should be absolutely fair and just, not using improperly the information obtained, but endeavoring to reach results which appear to be unquestionably correct. He must divest his mind of the innate desire to minimize the consequences of his decision to the Corporation, on the one hand, or to favor the State or his employer, on the other; it may be difficult, but on his ability to do this depends the success or failure of his work.

Considering the subject generally: in making the valuation of the physical property, the organization should consist of one man in charge, and under him a field organization and an office organization. The property, if large, should be divided into convenient districts,

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with a division engineer and necessary assistants in charge of each. Care should be taken that these assistants are competent men, though they are often hard to obtain for temporary work of this character, and there is not sufficient time in which to weed out and perfect an organization. They should be men of experience on the particular class of work to which they are assigned, and should be tactful and courteous. Stress should be laid on keeping plain, neat notes, not too crowded; on watchful care of the party working in the field, to prevent accidents, and on the necessity of absolute correctness in calculations and figures, in the multitude of which it is surprising how many mistakes will creep in unless special care is taken to check every step thoroughly. The office engineer should be equally competent, and accustomed to systematizing and analyzing, so that the results will be arranged systematically, not only as considered by themselves, but as far as possible according to the classification of the Interstate Commerce Commission, so that, no matter where made, they can be easily compared.

The work, if large, should be standardized. Everything to be reported should have a form for the purpose. These should be as concise as possible, calling attention to the essential information, but not in too much detail. Unit prices should be established after proper consideration.

Reproduction Value.—In ascertaining the reproduction value, the aim should be to obtain prices for which the material could be purchased and the work let to responsible parties at the date of the valuation. Real estate and depreciation are probably the two items in which there will be the largest differences in opinion as to values, and both should be determined by the personal examination of experts, following some prearranged system. One founded on the Somers system might do for the land, and certain percentages of depreciation per year, varying for the three conditions of good, fair and poor, for the structures and equipment, but the results in any case should be examined and passed upon by some one person so as to eliminate the individual equation as far as possible.

It is when the figures thus reached are before him that the Engineer finds himself confronted with many perplexing problems. To what items should percentages be added, and in what amounts? A small change in such items often makes a large difference in the total. There is not much trouble about general expenses, legal expenses, engineering, etc., as these are undoubtedly proper items to be added, and the amounts of the percentages are not difficult to determine from sufficient study of the property. Opinions on such matters will not vary greatly, but there is a difference with regard to such items as leasehold interests, solidification, contingencies, interest and taxes during construction, commissions and discounts on securities, working capital,

value of the good will, and considering the property as a "going concern," about which opinions will differ much more widely. Mr. Mordecai.

Leases from the company are like any other book asset. Leases to the company should be considered as the land is considered. What is the present value of the leasehold interest for the remainder of the term for which the rental is fixed?

Present Value.—In ascertaining the present value, it would seem that something should be allowed for solidification, the amount depending on the manner in which the work was built, its age, the likelihood of damage by the elements, etc. Possibly a percentage of appreciation on the value of the earthwork and masonry would be the fairest manner in which to consider it. Due care must be taken, however, to give proper credit to good work and not put a premium on inferior construction.

A percentage should be allowed for contingencies in all cases, but this is not necessarily the same for every piece of property. The estimate is made on a completed piece of work, consequently, if done with proper care, this item should not be as large as if the estimate were made for work to be constructed; but there are many things, not seen by the estimating engineer or disclosed by available records, which must be covered by this item, such as buildings bought with the land and afterward destroyed, damages paid for reasons not now apparent, difficulties encountered in excavating wet or hard material, amounts spent in dredging, in artificial and difficult foundations, losses during construction on account of strikes, washouts, etc. These are perfectly legitimate charges, and are likely to have occurred, and proper allowance should be made for them.

It would seem that interest and taxes during construction is a legitimate charge, and therefore, in the cost of reproduction, sufficient amounts should be added to cover it. Care should be taken to make the time long enough, as engineers are often too sanguine as to the length of time necessary to complete a certain piece of work. It is true that a part of a railroad, for instance, may be completed and opened for operation, but the net revenue derived would be very different from that of the completed road with its terminals and connections.

A new corporation can rarely market its securities at par, not only on account of the chances taken by the investor, but also because, being human, he likes to think he is buying at a bargain, getting something a little below its value; consequently, inducements vary from a small discount on bonds to a share or two of stock thrown in. To what extent a reasonable discount is a proper charge against construction may be considered an open question. It might seem fair that a certain fixed percentage be allowed in valuations, to determine capital for commissions and necessary discounts, varying according to the amount of the

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securities. This need not cover the whole amount of the discount, but only that portion which experience would consider essential in marketing unquestioned securities.

Consideration of the items working capital, good will, etc., may not properly belong to the Engineer, but rather to the Statistician, except as the former hears of such items being used as an argument against the necessity for a valuation of the physical property of a corporation. It is often asked, for instance, how can a value be placed on the property of the Pennsylvania Railroad Company, with its great commercial position, its magnificent terminals, and its splendid organization, all the result of the expenditure of much time and money? It is certainly a difficult problem, but the Pennsylvania Railroad is one of the greatest properties in America, possibly in the world, and because the proper valuation of this property is surrounded with difficulties it does not follow that the valuation of the properties of all other public service corporations are equally troublesome. The very difficulty of the task shows the importance of having firm ground for the first step. Having that, it may not be as hard as imagined to take others.

Thus it is seen that there are many perplexing questions for the Engineer to consider, and many details for him to work out, in doing which Mr. Riggs' paper will materially help. Above all, the Engineer must aim to be impartial; he must arrive at such a point of view as to see both sides with equal distinctness, and judge fairly and justly, trying to determine some well-defined laws and formulas which will serve as a basis in ascertaining the values desired.

Mr. Ruggles.

W. B. RUGGLES, M. AM. SOC. C. E. (by letter).—In his discussion Mr. Lavis quotes the case assumed by the *New York Sun*, of two bridges over the Ohio River—one between Cincinnati and Newport and one 20 miles below, between villages, etc.

In 1898 the writer was employed by the Board of Supervisors of Cincinnati to put a valuation on its Ohio River bridges for purposes of taxation, and the many points of view, as to their cost and their actual value to the owners and to the communities, were at that time, and have been frequently since, considered by him. In this particular valuation the duties of the Engineer were comparatively simple and plain, for, as there were sure to be controversies on two points at least, first, as to the right of the city to levy any tax on the bridges as such, and second, as to whether any control by the city extended to the center of the river, informally but generally recognized to be the division between the cities for police and similar purposes, or only to the northerly low-water mark, the limiting boundary to the "Territory Northwest of the River Ohio," as recognized by the ordinance of 1787, it appeared to the Board to be advisable, in the earlier stages of their efforts, to avoid, as far as reasonable, any controversies

concerning details of the valuation, and the writer was instructed to give the bridge companies the benefit of any doubts. Mr. Ruggles.

The railroad bridge of the Cincinnati Southern Railway, the one lowest on the river and having the little village of Ludlow at its southern end, and thus most nearly filling the conditions of one of the assumed structures of the *Sun*, is, with its railroad, the property of the city, and the Supervisors believed that, under the terms of the lease to the operating company, it should not be taxed.

Of the other four bridges, the Cincinnati and Covington Elevated Railway and Transfer Bridge—commonly known as the Chesapeake and Ohio Railway Bridge—the Covington and Cincinnati Suspension Bridge, the Central Railway and Bridge Company's Bridge, and the Newport and Cincinnati Bridge, commonly known as the Pennsylvania Railway Bridge (all noted in the order of occurrence, passing up the river), the writer had official or semi-official reports giving such details of at least the principal features of the structures that in a measure they supplied quantities, weights, and some prices; those lacking were either calculated from actual measurements taken on the structures or supplied from plans furnished by the companies, since, as the several companies relied on defeating the efforts of the supervision on legal grounds, they conceded values which otherwise might have been strenuously contested. As long as the writer knew anything of the results, the Board of Supervisors was unsuccessful in its purpose to get the bridges, as such, on the tax duplicates; but that has no particular bearing on the points raised in this discussion. Of the five bridges, three are primarily railroad bridges. The Cincinnati Southern Bridge has one footway only, on which it formerly collected tolls; all the others have footways and wagonways, and the three above the Chesapeake and Ohio Railway Bridge carry electric railways. The Newport and Cincinnati (Pennsylvania Railway) Bridge has all the features of steam and electric railways, wagonways and footways. In some particulars these bridges differ greatly, for instance, the bed-rock of the river lies at the surface of the most easterly (Pennsylvania Railway) bridge, and for each successive bridge is found deeper, as the river is followed westward, the river-span piers of the Chesapeake and Ohio Railway Bridge being 54 ft. below low water and those of the Cincinnati Southern Railway Bridge being likewise very troublesome.

The two bridges with exactly the same uses—double footways, wagonways, and electric lines—are the adjacent Suspension and Central Bridges, one having the City of Covington and the other the City of Newport at its southern terminus, but these differ most widely as to valuation. The Suspension Bridge, as reported to the writer by the late W. Hildenbrand, M. Am. Soc. C. E., with the consent of his company, was valued at only a little short of $1 000 000 as reinforced; that of the

Mr. Ruggles.

Central Bridge Company, as reduced from the reports of the engineers, was very nearly one-third, only, of that amount, both without any right of way, as real estate was in all cases listed separately. At that time, however, the traffic over the Suspension Bridge, counted in persons and vehicles passing over its several lines, was not far from as relatively greater than that of the Central Bridge as its valuation was higher, and it was more indispensably necessary, as the writer views it, than either the Central Bridge above, or the Chesapeake and Ohio Bridge below it, for in the thirty odd years of its use (it was completed in 1867), the adjoining communities had adjusted their lines of traffic to it, while that passing over the other two bridges occurred more because of little differences of convenience (not, however, to be considered otherwise than an important provision in traffic of such magnitude).

Disregarding other differences, such as the unit prices of 10 or 11 cents per lb. for iron paid by the Suspension Bridge Company in the time of the Civil War, compared with 4.47 cents per lb. for the new cable wire or 3.32 cents per lb. for the new structural steel, it appears to the writer that the element of more or less indispensable use by a community, as well as the greater freedom of movement in the river below by reason of there being no piers in the stream, are elements of value; but that they are items to be reduced to figures for the purpose of taxation is not so clear, any more than that there is equity in any demand that might be made that the New York Central and New York, New Haven, and Hartford Railroad Companies should be taxed on the additional $22 000 000 expended in the electrification of their lines about New York City for the comfort, convenience, and edification, not of the patrons of the roads alone, but of the public at large, without—as just concluded by an eminently able board—any marked economies in operation. There is no question in the writer's mind that any one line of railroad is several times more valuable to each individual in inland regions, such as Mexico and Arizona, than an equal mileage in Connecticut with its Sound harbors, steamship lines, good wagon roads, and numerous but non-competing railways, partly because of the relative usefulness, for which no practicable substitute could be found, and partly because these newer States have not entered on all these multifarious lines of governmental activities, such as policing and safeguarding for public health and the like, and, much as funds are everywhere desirable, could possibly defer for a time some of these developments of civic zeal. It does not appear, therefore, that the discriminations in valuations disclosed by the author's Table 1 are altogether without a good basis in relative convenience, although clearly extreme; but, as the law of most States is understood by the writer, such discriminations may not usually be made with strict regard for the legality of tax assessments.

Mr. Ruggles.

It is true, as remarked by Mr. Riggs, that a bridge is, of itself, not usually a desirable feature of a railroad, but it must be clear that if there were no river between Cincinnati and her sister cities in Kentucky, communication between the two States might be entirely free, and the business opening for toll bridges would not exist; consequently, in these particular cases, the bridges cannot be considered undesirable.

One other consideration bearing on values has been at least suggested by the study of the Cincinnati Suspension Bridge. It is, as indicated, the oldest river bridge at Cincinnati, the second or third oldest over the Ohio River, and, though repaired and strengthened, it has never been supplanted by an entirely new superstructure. The next oldest bridge is the pin-connected Pennsylvania Railway Bridge, built five years later than the Suspension Bridge, but, at the time of this valuation, it had been entirely replaced by quite a different structure—even the masonry was largely rebuilt. In a degree this comparative facility with which provisions for the greater loads can be provided without condemnation of the leading features of the structures has been shown in the Brooklyn and Niagara Bridges, though not by any means perfectly, but the point the writer would make is that this element of ease of reinforcement, or with which provision can be made for greater loads, is to be considered in the author's "Physical Property Elements of Value," as doubtless he has concluded.

Mr. Riggs.

HENRY EARLE RIGGS, M. AM. SOC. C. E. (by letter).—The discussion of this paper has been so full, and so much of it is devoted to bringing out methods of valuation not fully covered in the paper, that it does not appear to the writer desirable to do more than to clear up one or two matters which may have been left somewhat ambiguous in the paper, and to review the main points on which there is apparent disagreement among engineers who have engaged in valuation work.

The writer wishes to express, to those who have added so materially to the value of the paper by their discussion, his sincere appreciation and his thanks, and he regrets that, owing to the length of the paper and the extent of the discussion, it will be impossible to review all the points raised.

It would appear that there are a few matters in regard to which the writer did not succeed in making his views entirely clear; consequently, a few words on these items may not be amiss.

Overhead Charges Versus Unit Values.—The point raised by Mr. Higgins, that the determination of any percentage figures to be applied to cover overhead charges must be carefully considered in connection with the unit prices that have been adopted and applied to the items of the physical inventory, is well taken. On all valuation work with which the writer has been connected the various local conditions

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were taken into account, and, for each item a figure was used which, it was believed, would fairly represent such price as would be named by a contractor for the work under the existing conditions. Therefore, all elements of hazard to contractors, and contractors' profits, have been included in the unit price, leaving to be treated under overhead charges only those elements of cost which the corporation under investigation would be compelled to bear.

The determination of a proper set of unit prices for a valuation involves a very careful study of prices and local conditions, so that it would appear to be impossible to establish any fixed rule which would be generally applicable to all appraisals. If the unit prices adopted be the cost to a contractor, then the overhead charges must be made large enough to cover the contractor's hazard and profit. Every appraisal should be accompanied with a report or statement, showing clearly what has been done in this matter.

Items to be Inventoried.—In reference to the items to be inventoried, the construction placed on one sentence by Mr. Newton is entirely foreign to the meaning which the writer intended to convey. Mr. Newton's statement of his own views is entirely in harmony with those of the writer.

Discount.—Messrs. Henry C. Adams and W. H. Williams have both discussed discount, and both take exception to the conclusions of the writer. This would appear to be a subject on which there is disagreement in all professions. Very able and experienced railway managers and accountants will be found on both sides. Since the paper was written, the writer has been engaged on the appraisal of a comparatively new property which was defendant in a condemnation suit. In this case, 20-year bonds were issued in 1905, and sold at an average discount of 15 per cent. The discount has been treated as an interest charge on the books of the company, and was being written off from year to year. The question arose: Should the discount balance (approximately three-quarters of the discount) be added to the physical value and paid by the parties acquiring the property; or should the loss be sustained by the owner? The treatment of the account on the books of the company was in exact accord with the writer's first contention, but a careful study of the case in hand led to the conclusion that equity demanded inclusion of the unamortized discount in this case. Had the condemnation taken place in 1925, after all the discount item had been charged against operation, no part of this amount would appear to be proper in an appraisal. This case is cited as being the only one which has come up in the writer's practice in which he has been inclined to recognize the propriety of including the item. The writer is not yet convinced that his first conclusion was in error.

Professor Adams suggests several different claims made as to the

discount item. If any one of them be adopted, has suitable agreement been advanced for treating the item as a capital charge? Clearly, the amount of money involved in the discount item is not paid by the company until the maturity of the bond. It is not invested in the physical property of the company until it is paid. If written off from year to year and charged against operation, or treated as a deduction from earnings or from surplus, it would hardly seem proper to include it in capital at the end of the period. The writer is open to conviction, but he has not yet been convinced of his error on this point. Happily, this is an item, the amount of which may be exactly determined from the books of any company under investigation; so that, whatever the final determination may be as to the propriety of its inclusion in an appraisal, the amount to be treated is not a matter of estimate. Mr. Riggs.

One Value Versus Several Values.—The writer has called forth discussion on this point from several members, and, in view of some of the discussion, he believes that a few sentences may tend to clarify his views:

(1) An appraisal should be in complete detail, and should show fully, not only all schedules of physical property and of unit costs and depreciation percentages on which physical values are based, but should completely detail all schedules based on an examination of the books.

(2) The final summary should include every element of value which enters into the property, and which should enter into the "fair value" or "true value" of the property, if valued for any purpose whatsoever.

(3) An assessed value for taxation purposes should not necessarily include all the items in the engineering valuation; but an assessment can be made with absolute fairness if all the facts are at hand and in such form that non-taxable items are separable.

(4) If rate-making or the sale of the property be the ultimate object, the work of making rates or of negotiating the sale can be carried on to better advantage with a complete appraisal than with an incomplete one.

(5) The work in the States of Minnesota and Washington was done with one object in view. It was ultimately used for another purpose. If a low valuation is deliberately made for taxation purposes, serious embarrassment is likely to arise when rate legislation is contemplated. It will be very difficult for an engineer to sustain his position when he submits one "true value" or "fair value," with the expectation that it will be used as a figure for assessed valuation, and another and radically different one as a basis for rate-making. It would appear to be much easier to submit a complete set of schedules, showing the cost of reproducing the physical property, depreciation, present physical value, together with all other elements affecting the final value, and then to point out that certain modifications would appear to be proper in an assessment for taxes.

Mr. Riggs.

(6) The actual making of rates or of assessments for taxation is not a duty usually assigned to a body of engineers.

Mr. Dana's discussion is directed to this phase of the subject, and brings out a number of points which are suggested above very fully.

This is a matter on which engineers have radically differed in practice, and it involves a principle of valuation which should be finally determined as soon as practicable. Further discussion in connection with this paper would hardly accomplish any definite end, therefore it is left, with emphasis on the fact that there are radical differences of opinion regarding it.

Going Concern.—The discussion of this paper, taken in connection with the paper by Mr. Alvord before the American Water-Works Association, and the recent paper by Messrs. Metcalf and Alvord,* brings out clearly three points of view:

(1) That of Professor Henry C. Adams, stated by him in various publications, and advocated by the writer in the paper: That there is no going concern value, as such, but that all intangible elements of value merge into one non-physical value, which may be determined by a study of the income accounts of the particular property under investigation.

(2) The "Wisconsin Method," sometimes called the Cooley Method. The general principles of this are described so fully and so clearly in Mr. Gillette's discussion, under the head of Development Expense, that further explanation is unnecessary.

(3) The method advocated by Mr. Metcalf in his able discussion of this paper, and by Messrs. Metcalf and Alvord in their paper.

The writer cannot concede the accuracy of the position of Mr. Burns, that interest during construction should be eliminated from the physical valuation of the property and included as part of the "going value." Interest during construction is no less a part of the actual cost of constructing the property than the rails in a railroad or the water pipe in a water-works plant. Nor can the writer accept Mr. Metcalf's optimistic view of the probable action of the Supreme Court when it will be called on to pass squarely on the "going concern" value in a rate case. Mr. Metcalf says:

"Certainly, as applied to water-works valuation, Mr. Riggs' statement is not justified. The Maine cases clearly include going value as an element of value on which rates should be predicated; by inference, so does the Kansas City case. In the Knoxville case it was in fact allowed by the Master."

This is all true. The Knoxville case, however, reached the Supreme Court, and the Supreme Court squarely side-stepped "going value" in the following words:

* This paper will be published in a subsequent volume of *Transactions*, Am. Soc. C. E.

"We express no opinion as to the propriety of these two items ['organization promotion, etc.,' and 'going concern'], in the valuation of the plant for the purpose for which it was valued in this case, but leave that question to be considered when it necessarily arises." Mr. Riggs.

Judge Lurton, in upholding an intangible value in the Omaha case, and quoting among others the Kansas City case and the Gloucester and Norwich cases, which approved and followed the Kansas City case, significantly adds:

"No such question was considered on Knoxville Water Co. [212 U. S., 1] or Wilcox *vs.* Consolidated Gas Co. [212 U. S., 19]; both cases were rate cases, and did not concern the ascertainment of value under contracts of sale."

The writer quite inclines to the views expressed by Mr. Gillette, and fails to read any approval of "going concern" or "going value," as advanced by our water-works brethren, when the determination of a value on which to base rates is the issue.

That there is sound logic in Mr. Gillette's argument for development expense—which differs in the last analysis but little from Mr. Metcalf's presentation of "going value"—the writer will admit. There are many corporations in existence to-day which have made substantial investments in creating a successful business after the physical plant was completed and in operation. It hardly seems equitable that such an investment should not be taken into account in fixing a value. The real difficulty lies in drawing the line between the really valuable property, and one which is truly a profitable investment, and that property which, by reason of poor business judgment in its creation, faulty or uneconomical construction or bad management, is not earning a reasonable profit.

The writer has given some study to the theory advanced by Professor Cooley in the Milwaukee Street Railway case, and later adopted by the Wisconsin Commission in the Antigo Water case, but is not yet ready to accept it. The hypothetical curve appears to be acceptable and reasonable, but the actual application of the formula to cases which have come under the writer's attention, fails to show a profit at the end of a period of years. If the rule be stated: "the greater the deficit in earnings the greater the value," then this method may be of general application, but it does not appeal to the writer as sound business to advocate the assigning of any non-physical or "going" value to a property unless the property has, for some years, actually been earning a return on the investment which is large enough to justify fully the claim that it is worth more than it cost, or more than its present physical value. If, during the first few years, there was a deficit, due to the expense of creating the demand for the commodity produced and building up the business to a profitable condition, it may be sound

Mr. Riggs.

to include this element in an appraisal. The actual cost may be determined, but the cost of reproduction is pure speculation. The actual cost of a ton of rail, a locomotive, a boiler, or the copper for a transmission line bought fifteen years ago may be radically different from the cost of reproduction of the same physical things to-day; but that cost of reproduction is radically determined as the things are being bought and sold in the open market. Not so, however, with the development charge, or cost of creating a business. Conditions are not the same, they may not be at all similar.

Without arguing the subject further, the writer submits that this is a matter that requires the greatest of care in its treatment. The adoption of any rule which will assign a "going value" to a property which has been managed so that it not only has never earned a large return on the investment, but has not taken care of depreciation—a property which would not appeal to financial men as a sound investment at its physical valuation—will not only be difficult to sustain in the Courts, but will tend to discredit the entire subject of valuation.

The writer's present feeling is that the term "going concern" ought to be eliminated from the nomenclature of valuation practice, and that scant consideration ought to be given to any attempt to include anticipated profits in any manner in a valuation.

Mr. Kuichling has suggested that some further data as to the Michigan Appraisal might be of value. Unfortunately, the writer has not in available form information as to different classes of railroads. Table 15, based on the average of all the roads in Michigan, was prepared by James Walker, Chief Engineer of the Michigan Board of State Tax Commissioners, after the completion of the Michigan Appraisal. Column 2 gives the percentage of each item to the entire cost of reproduction. Column 3 gives the average percentage of conditions. The remaining four columns give the average cost of reproduction per mile on various mileage bases.

It must be borne in mind that Michigan is geographically unlike any other State in the Union, that the mileage of high-class main-line railroad is relatively small, and that there is a large mileage of cheap branch lines and logging roads. As a result, these general averages are of little value for comparison with similar figures in other States, where trunk-line mileage forms a greater percentage of the entire mileage.

In closing, the writer believes that it is but justice to himself to correct a few misleading statements in Mr. Williams' discussion which might cause serious misunderstanding of the writer's views.

Mr. Williams refers to his discussion of Professor Adams' paper before the American Economic Association in December, 1909, he also again refers to the same paper, and conveys the impression that

the writer discussed this particular article in the paper before this Society. Mr. Riggs.

Reference to page 105 will show that the writer did not refer to this paper (which, in fact, he did not see until his own paper was in print), but to one written by Mr. Williams in January, 1909, and given the widest publicity, not only by its distribution in pamphlet form, but by publication in the columns of *Railway Age Gazette*.

TABLE 15.

Item.	Percentage of each item to entire cost of reproduction.	Present value. Cost percentage.	Cost per Mile, on Basis of: Main track. 7 082 miles.	Main track and branches. 7 813 miles.	Main track, branches, spurs, and sidings. 10 718 miles.	Main track, branches, spurs, sidings, and second track. 10 883 miles.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. Engineering	2.7	100	761	689	503	495
2. Right of way	13.7	100	3 918	3 551	2 589	2 542
3. Real estate	0.4	100	122	110	81	79
4. Grading	10.7	99.9	3 064	2 777	2 025	1 994
5. Tunnels	0.6	95.2	162	147	107	100
6. Bridges	4.0	78.9	1 133	1 027	749	738
7. Ties	5.5	55.2	1 573	1 426	1 040	1 024
8. Rails	14.1	76.2	4 052	3 673	2 678	2 637
9. Track fastenings	1.9	77.7	543	492	359	353
10. Frogs, switches	0.7	70.7	207	188	137	135
11. Ballast	1.8	100	525	477	347	342
12. Track laying	3.2	97.6	926	839	612	602
13. Fencing	1.4	58.9	390	354	258	254
14. Crossings	0.3	70.5	86	78	57	56
15. Interlockers	0.2	89.4	71	64	47	46
16. Telegraph	0.1	52	36	33	24	24
17. Stations	0.2	75.7	580	526	384	378
18. Shops	0.1	68	305	276	202	198
19. Shop machinery	0.5	79.6	156	142	104	102
20. Water stations	0.4	71.9	103	93	68	67
21. Fuel stations	0.1	66.4	43	38	29	28
22. Elevators	0.6	75.5	189	171	125	123
23. Warehouses	0.1	71.1	37	35	24	24
24. Docks and wharves	2.7	69.3	781	708	516	507
25. Miscellaneous structures	0.6	69.4	174	158	115	113
26. Locomotives	4.4	56.4	1 274	1 154	842	829
27. Passenger equipment	1.6	71.2	452	409	299	294
28. Freight equipment	9.7	69.4	2 787	2 525	1 841	1 813
29. Miscellaneous equipment	0.3	60.3	99	90	66	65
30. Ferries and steamers	0.8	63.5	244	221	161	159
31. Electric plants	0.004	96.6	13	12	9	9
32. Terminals	.....	.....	....	.....	.....	.....
33. Legal expenses	0.3	100	95	86	63	62
34. Interest	2.6	100	747	677	494	486
35. Organization	1.3	100	373	339	247	243
36. Contingencies	9.1	82	2 602	2 358	1 712	1 695
37. Total cost	100	82.1	28 623	25 945	18 914	18 627

The writer does not care to permit to go unnoticed the imputation that he has attacked railroad officials as a class. If such inference is to be drawn from his paper, he desires to correct it.

Mr. Riggs.

The writer was in railway service for some years, for six years in an official position. For the past fifteen years he has been, at frequent intervals, on special service for railroads. He is at present under employment by two of the principal railways of the country. He has many warm friends in the service, many in official capacities, and he is fully cognizant of the high ability, integrity, and loyalty of railway employees, and by employees he means to be understood as including all classes, from the highest officials down.

Inasmuch as our railroads form our greatest industry, and inasmuch as the active heads of the large roads have under their control such properties as but few in other fields are called to administer, it follows that there are hundreds—yes, thousands—of men in railway service, competent to fill any office in the land. The writer repeats: it is a pity that the demands of their work are such that they cannot give more of the benefit of their highly specialized training to the public service, and that they have so often apparently misunderstood or misconstrued the perfectly honest attempts of public officials to find a remedy for real evils.

In closing, the writer desires to say that he regrets the impossibility of treating the subjects of depreciation and fair return in a satisfactory manner without unduly lengthening this discussion.

It may not be out of place to say that, in the writer's opinion, a fair return on the average public service corporation property should be considerably in excess of the figures usually named. There is but little incentive to invest in railways, street railways, or other public service corporations, if the limit of return is to be 7%, or 8%, or even 10%, on the actual investment. This is especially true where the hazard of investment is increased by term franchises under which the companies are operating. The writer has the most absolute confidence in the ability and integrity of our Supreme Court, and is led to believe that, on a proper showing, confiscation will not be permitted.

He also believes that, in general, the great mass of intelligent people wish only absolutely fair dealing with the corporations.

On making a full and frank showing of facts and conditions, the public service corporation which is honestly financed and honestly operated, need have little fear of ultimate justice.

The public service corporation which is administered, not to render service to the public, but to permit stock speculators to reap a harvest, can hardly hope for the same brand of justice, and it is hardly to be expected that such a corporation will welcome publicity.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

TRANSACTIONS

Paper No. 1191

WATER PURIFICATION PLANT, WASHINGTON, D. C. RESULTS OF OPERATION.*

By E. D. Hardy, M. Am. Soc. C. E.

With Discussion by Messrs. Allen Hazen, George A. Johnson, Morris Knowles, George C. Whipple, F. F. Longley, and E. D. Hardy.

The Washington filtration plant has already been fully described.† At the time that paper was written (November, 1906), the filtration plant had been in operation for only about 1 year. It has now been in continuous operation for 5 years, and many data on the cost, efficiency, and methods of operation, have accumulated in the various records and books which have been kept. It is thought that a brief review of the results, and a summary of the records in tabular form, will be of interest to the members of the Society, and it is also hoped that the discussion of this paper will bring out the comparative results of operation of other filter plants. As a matter of convenience, the following general description of the plant is given.

Description of the Filtration Plant.—The Washington filtration plant was completed and put in operation in October, 1905. It consists of a pumping station for raising the water from the McMillan Park Reservoir to the filter beds; 29 filters of the slow sand type, having an effective area of 1 acre each; the filtered-water reservoir,

* Presented at the meeting of February 15th, 1911.

† "Works for the Purification of the Water Supply of Washington, D. C.," by Allen Hazen and E. D. Hardy, Members, Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LVII, p. 307.

having a capacity of about 15 000 000 gal.; and the necessary piping and valves for carrying water, controlling rates of filtration, etc.

In the pumping station, there are three centrifugal pumps, which are directly connected to tandem compound engines; two sand-washer pumps; three small electric generating sets for furnishing electric light; and four 200-h.p., water-tube boilers.

Each of the centrifugal pumps has a nominal capacity of 40 000 000 gal. per day when pumping against a head of 21 ft., and each sand-washer pump has a capacity of 2 500 000 gal. when pumping against a head of 250 ft. The electric light engines and generators supply the current for lighting the pumping station, the office and laboratory and other buildings, and also the courts and interior of the filter beds, and for operating a machine-shop.

The filters and filtered-water reservoir are built entirely of concrete masonry. The floors are of inverted groined arches on which rest the piers for supporting the groined arch vaulting. All this concrete work is similar to that in the Albany, Philadelphia, and Pittsburg filters.

The filters contain, on an average, 40 in. of filter sand and 12 in. of filter gravel. The gravel is graded from coarse to fine; the lower and coarser part acts as part of the under-drain system, and the upper and finest layer supports the filter sand. The raw water from the pumps is carried to the filters through riveted steel rising mains which have 20-in. cast-iron branches for supplying the individual filters. The filtered water is collected in the under-drainage system of the several filter beds, and is carried through 20-in., cast-iron pipes to the regulator-houses. These regulator-houses contain the necessary valves, registering apparatus, etc., for regulating the rate of filtration, showing the loss of head, shutting down a filter, filling a filter with filtered water from the under-drains, and for turning the water back into the raw-water reservoir, or wasting it into the sewer. From the regulator-houses, the filtered water flows directly to the filtered-water reservoir. Generally, five filters are controlled from one house, but there are two cases where the regulator-houses are smaller, and only two filters are controlled from each.

The dirty sand removed from the filters is carried by a portable ejector through one or more lengths of 3-in. hose and a fixed line of 4-in. pipe, to the sand washers. From the sand washers, the washed sand is carried to the reinforced concrete storage bins, each of which

has a capacity of 250 cu. yd., and is at such an elevation that carts may be driven under it and loaded through a gate.

Until April, 1909, the sand was replaced in the filters by carts which were filled through the gates in the sand bins. It was then hauled to the top of the filter beds and dumped through the manholes on the chutes, which could be revolved in any direction. These chutes were used to prevent the sand from being unduly compacted in the vicinity of the manholes, and to facilitate spreading it in the filters. Since April, 1909, all the sand has been replaced by the hydraulic method. An ejector is placed under the gate in the sand bin, and the sand is carried in a reverse direction from the bin through the 4-in. piping and one or more lengths of hose to the filter bed. This process has lowered the cost of re-sanding considerably, and present indications are that it will prove entirely satisfactory in every way.

The average effective size and uniformity coefficient of the filters are shown in Table 1.

TABLE 1.—FILTER SAND AS ORIGINALLY PLACED.

Filter No.	Average effective size, in millimeters.	Average uniformity coefficient.	Depth of sand, in inches.	Average turbidity.
1	0.32	1.88	35.3	2 600
2	0.30	1.78	37.7	2 200
3	0.32	1.77	40.2	3 000
4	0.29	1.80	42.5	1 800
5	0.34	1.74	44.9	2 700
6	0.31	1.78	37.7	2 300
7	0.29	1.72	40.1	2 300
8	0.32	1.75	40.2	2 800
9	0.32	1.78	42.5	2 900
10	0.30	1.69	39.5	2 500
11	0.34	1.93	37.1	2 600
12	0.29	1.66	34.7	2 100
13	0.32	1.83	33.6	3 500
14	0.29	1.66	33.6	2 600
15	0.33	1.75	39.0	2 400
16	0.33	1.78	42.3	3 000
17	0.33	1.86	45.5	3 300
18	0.34	1.80	48.7	3 100
19	0.34	1.80	52.0	.....
20	0.34	1.87	39.0	2 700
21	0.32	1.82	42.3	2 400
22	0.33	1.74	45.5	2 200
23	0.33	1.81	48.7	2 300
24	0.35	1.80	52.0	2 600
25	0.29	1.64	39.5	2 400
26	0.31	1.71	37.1	2 100
27	0.31	1.71	34.7	1 900
28	0.33	1.93	33.6	2 300
29	0.34	1.93	33.6	3 000
Maximum...	0.36	1.93	52.0	3 300
Minimum....	0.29	1.64	33.6	1 800
Average.....	0.32	1.77	40.4	2 600

Description of Washington Aqueduct.—The water supply of Washington is taken from the Potomac River, at Great Falls, about 16 miles above the city. At that place, a dam has been built across the river, which holds the water at an elevation of 150.5 ft. above mean tide at Washington. From Great Falls the water flows by gravity for a distance of 16 miles through a 9-ft. conduit, three reservoirs, and a tunnel. From McMillan Park Reservoir, the last of the three, the water is lifted by centrifugal pumps about 21 ft. to the filters. After passing through the filters, it flows to the filtered-water reservoir, and later to the city mains. In its passage from Great Falls to the filters, the water flows through three settling reservoirs, which have already been referred to. These reservoirs are known as the Dalecarlia, the Georgetown, and the McMillan Park Reservoirs, and have available capacities of 141 000 000, 140 000 000, and 180 000 000 gal., respectively.

Turbidity.—The Potomac River water is rather turbid, the turbidity being caused by very fine particles of clay. The river is subject to sudden fluctuations, it being no uncommon thing to have a turbidity of 100 one day, and 1 000 the next. The high turbidity usually disappears about as rapidly as it comes, and is seldom higher than 500 for more than 5 days at a time. It is frequently the case, however, that a succession of waves of high turbidity will appear so close together that the effect of one has not disappeared before that of another is felt.

The clarification of the water supply begins at the dam at Great Falls. Here it is a clarification by exclusion, for when an excessive quantity of mud appears in the river water, the gates are closed, and the muddy water is allowed to flow over the dam and form mud-bars in the Lower Potomac, while the city is supplied from the water stored in the three settling reservoirs. Until a comparatively recent date, the excessively muddy water was never excluded, having been taken, like other decrees of Providence, as it came.

During the summer of 1907, the practice of shutting out water with a turbidity of 500 or more was established for the warm months. This practice was discontinued during the cold months, as it was feared that a very high consumption of water might occur at the time of low water in the reservoirs, and so cause a partial famine. During the winter of 1909-10, however, the gates were closed, as was the practice throughout the summer months.

When the reservoirs are well filled, and the consumption of water

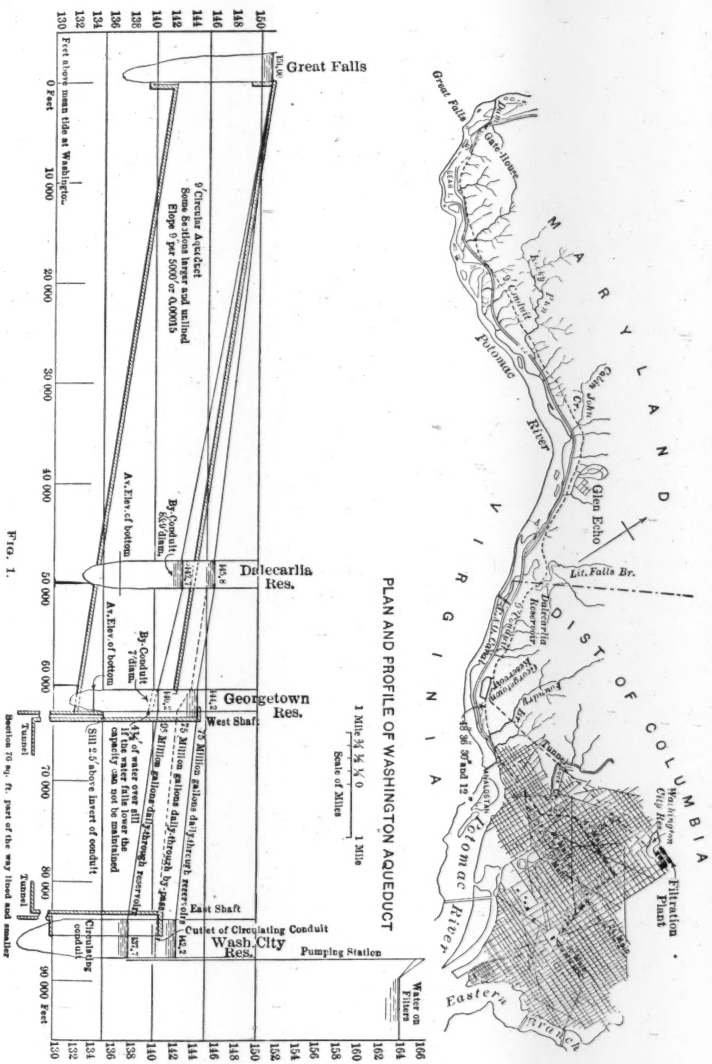

PLAN AND PROFILE OF WASHINGTON AQUEDUCT
Great Falls
Dalecarlia Res.
Georgetown Res.
Wash. City Res.
Pumping Station
Water on Filters
Cutlet of Circulating Conduit
East Shaft
West Shaft
Tunnel
Section 70 sq. ft. part of the way lined and smaller
Feet above mean tide at Washington
0 Feet
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000 Feet
9' Circular Aqueduct
Some Sections larger and unlined
Slope 9' per 5000' or 0.00015
Av. Elev. of bottom
By-Conduit 8 3/4' diam.
By-Conduit 7' diam.
75 Million gallons daily through reservoirs
85 Million gallons daily through by-pass
4 1/2' of water over sill if the water falls lower the capacity can not be maintained
Sill 2.5' above invert of conduit
Circulating conduit
1 Mile 3/4 1/2 1/4 0 1 Mile
Scale of Miles
MARYLAND
VIRGINIA
DIST. OF COLUMBIA
Great Falls
Gate-House
Potomac River
Glen Echo
Lit. Falls Br.
Dalecarlia Reservoir
Georgetown Reservoir
Washington City Res.
Filtration Plant
Eastern Branch
Tunnel

FIG. 1.

is less than 70 000 000 gal. per day, it is safe to close the gates at Great Falls for a period of about 4 days.

While a considerable reduction in turbidity is effected in each of the reservoirs, the bulk of the mud is deposited at the upper end of Dalecarlia Reservoir. This reservoir had become so completely filled, that, in 1905, it was necessary to dredge a channel through the deposit, in order to allow the water to pass it. During the summers of 1907 and 1908, a 10-in. hydraulic dredge removed more than 100 000 cu. yd. of mud which had been deposited in this reservoir. The mud deposited in Georgetown and McMillan Park Reservoirs is so fine that the accumulation of many years is not very noticeable in its effect on the depth of water.

The particles of clay which remain in the water after its passage through the three reservoirs, are so exceedingly small that they do not settle out in any reasonable length of time. Even the filtration of the water through one or more slow sand filters occasionally fails to remove the last trace of turbidity. This is especially true in the colder months, and not a winter has passed when the water supply has not been noticeably turbid at some time.

A general idea of the quantity of mud contained in the river water, the quantity excluded by closing the gates at Great Falls, and that removed by sedimentation and filtration, may be gained from Table 2, which is, of course, only a rough approximation.

Table 2 also shows that the gates were closed 10.50% of the time, thereby excluding 40.06% of the total suspended matter which otherwise would have entered the system.

The turbidities, bacterial counts, and chemical analyses of numerous samples of water are shown in Tables 3, 4, 5, and 6. The amount of work done in the pumping station, average consumption of water, death rate from typhoid fever, and filter runs are shown in Tables 7, 8, 9, and 10.

Raking.—At the time the filters were first put in service, the sand bins had not been completed, and, consequently, the work of cleaning the filters was carried on in the old-fashioned way of scraping by hand and wheeling out the sand in barrows. This method of cleaning was used from October, 1905, to April, 1906; then the regular sand-handling system was commenced.

At times, during the first two summers the filters were in operation,

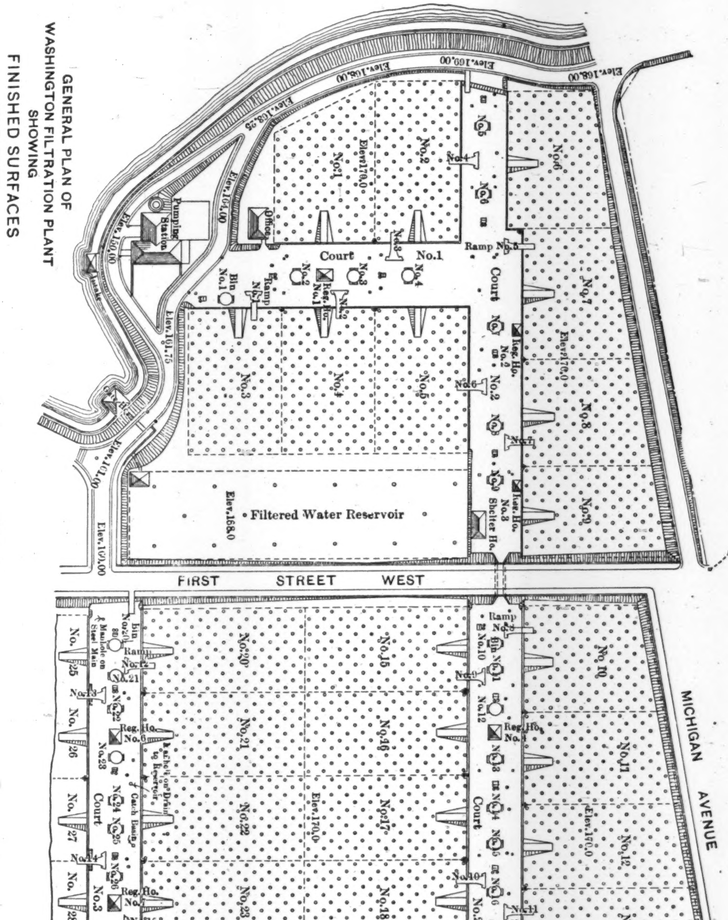

GENERAL PLAN OF
WASHINGTON FILTRATION PLANT
SHOWING
FINISHED SURFACES
SCALE OF FEET
0 50 100 150 200 250
Elev. 169.00
Elev. 168.00
Elev. 168.25
Elev. 164.00
Elev. 150.00
Elev. 161.75
Elev. 161.00
Elev. 160.00
Elev. 170.0
Elev. 168.0
Pumping Station
Office
Intake
Gate Ho.
Court
No. 1
No. 2
No. 3
Bin No. 1
Ramp No. 1
Ramp No. 5
Reg. Ho. No. 1
Reg. Ho. No. 2
Reg. Ho. No. 3
Reg. Ho. No. 4
Reg. Ho. No. 5
Reg. Ho. No. 6
Reg. Ho. No. 7
Shelter Ho.
Filtered Water Reservoir
FIRST STREET WEST
NORTH CAPITOL STREET
MICHIGAN AVENUE
Bin No. 20
Ramp No. 12
Manhole on Steel Main
Manhole on Drain to Reservoir
Catch Basin
Manhole on Drain to Sewer

FIG. 2.

considerable difficulty was experienced in keeping them cleaned as fast as was necessary to provide an ample supply of filtered water. For a short period in each summer it was found necessary to organize night shifts, and keep the work of cleaning in progress for from 16 to 24 hours per day.

TABLE 2.—TONS OF SUSPENDED MATTER ENTERING SYSTEM, ETC.

Month.	Amount that would have entered the system if the gates had been left continuously open.	Number of hours gates were closed.	Amount shut out.	Amount deposited in Dalecarlia Reservoir.	Amount deposited in Georgetown Reservoir.	Amount deposited in McMillan Park Reservoir.	Amount entering filtration plant.	Total.
1909.								
July	318	32.0	3	0	125	74	116	318
August	146	47.0	1	0	78	38	29	146
September	97	57.0	7	21	13	38	18	97
October	61	90.5	8	7	9	25	12	61
November	50	60.0	4	13	5	17	11	50
December	370	99.0	126	108	33	59	44	370
1910.								
January	2 410	136.0	1 109	1 020	67	117	97	2 410
February	839	117.5	481	126	56	75	101	839
March	208	7.5	13	43	15	13	124	208
April	321	65.0	17	195	43	43	23	321
May	197	84.5	58	54	22	24	39	197
June	1 505	124.0	786	535	49	88	47	1 505
Total	6 522	920.0	2 613	2 122	515	611	661	6 522

In order to relieve the situation at such times, the expedient of raking was tried. This was first attempted with the filters filled with water; the effluent was first shut off in order to prevent a downward flow of water, and the filter was then raked or harrowed from boats. This method was not satisfactory, however, as the work was neither as uniform nor as thorough as necessary. Later, the filters were drained to the necessary depth, and the surface of the sand was thoroughly stirred with iron garden rakes. The filters were then filled with filtered water through the under-drains and put in service.

This latter method proved so satisfactory that it has been resorted to at all times when the work was at all pressing. When the runs were of short duration, and the depth to which the mud had penetrated the filter sand was slight, a raking seemed to be nearly as effective in restoring the filter capacity as a scraping; it could be done in 8 hours by 3 laborers, and there seemed to be no ill effects from lowered efficiency.

TABLE 3.—Turbidities.

Average by Months.

(United States Geological Survey Standard.)

Month.	Great Falls.		Reservoirs:							
			Dalecarlia Outlet.		Georgetown Outlet.		McMillan Park Outlet.		Filtered water.	
1905.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
October	100	36	40	21	32	18	20	11	4	1
November	35	19	34	19	22	14	14	11	3	1
December	1 500	199	250	84	150	74	95	39	14	6
1906.										
January	700	94	180	60	130	60	85	52	20	12
February	120	45	85	41	55	29	35	22	5	3
March	1 750	272	350	181	120	56	90	46	8	6
April	1 270	167	180	72	95	58	75	46	12	7
May	600	56	50	30	45	16	34	10	3	2
June	1 700	303	500	125	450	94	180	41	13	2
July	1 000	130	180	54	150	47	250	43	13	3
August	1 530	375	250	112	95	66	65	45	5	2
September	120	33	180	34	95	28	75	25	7	2
October	1 025	127	110	37	60	24	55	21	1	1
November	160	27	75	20	45	16	24	13	1	1
December	600	69	110	31	80	28	80	26	8	2
1907.										
January	400	135	150	70	110	75	70	53	11	7
February	55	26	26	15	36	16	40	17	5	2
March	950	248	180	77	130	70	90	57	7	4
April	200	47	80	33	60	30	45	24	4	2
May	130	29	40	18	26	15	14	9	1	1
June	400	104	160	48	75	32	40	18	1	1
July	600	114	130	61	78	47	45	31	1	1
August	800	73	130	35	85	26	30	14	1	0
September	600	129	*	*	150	51	70	28	1	0
October	75	32	*	*	65	28	75	26	4	0
November	300	97	*	*	100	45	45	23	2	1
December	680	135	*	*	180	61	100	46	10	4
1908.										
January	2 100	202	340	73	250	82	160	65	20	7
February	3 000	302	300	52	150	52	75	32	7	4
March	300	91	150	78	100	68	65	42	5	4
April	75	23	65	41	37	27	26	20	3	2
May	2 000	172	130	48	85	37	50	20	1	1
June	400	40	70	29	40	24	30	18	1	1
July	1 500	149	....	74	170	44	75	15	0	0
August	900	129	200	*	150	56	85	39	2	1
September	75	24	*	*	50	19	35	18	0	0
October	95	20	*	*	55	18	28	15	0	0
November	24	11	*	*	20	11	19	10	0	0
December	20	9	17	11	14	9	10	7	0	0
1909.										
January	400	72	95	32	60	23	25	16	4	1
February	650	194	120	64	90	51	55	35	4	3
March	250	51	*	*	90	44	60	37	8	4
April	750	98	*	*	130	42	76	31	2	1
May	480	57	*	*	30	19	30	12	2	1
June	650	141	*	*	120	51	80	30	1	0

* Reservoirs out of service.

TABLE 3.—(*Continued.*)

Month.	Great Falls.		Reservoirs: Dalecarlia Outlet.		Georgetown Outlet.		McMillan Park Outlet.		Filtered water.	
1909.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
July	400	48	*	*	215	.46	120	35	2	1
August	180	23	*	*	50	17	18	9	0	0
September	26	16	24	14	*	*	25	6	0	0
October	14	10	15	10	11	9	8	4	0	0
November	11	9	11	8	10	8	6	4	0	0
December	600	63	110	31	80	28	50	15	3	0
1910.										
January	3 000	357	200	58	150	53	115	30	5	2
February	3 000	143	150	55	120	50	100	36	7	4
March	210	36	100	35	95	38	100	43	9	5
April	350	55	100	25	55	18	25	8	1	0+
May	300	33	55	19	50	17	28	13	1	0+
June	1 500	246	180	42	110	37	50	16	1	0+
Fiscal years:										
1905-06†	1 750	133	500	70	450	47	180	31	20	5
1906-07	1 530	114	250	46	150	37	250	29	13	2
1907-08	3 000	117	340	53	250	45	160	31	20	2
1908-09	1 500	79	200	50	170	32	85	22	8	1
1909-10	2 100	86	200	30	215	29	120	18	9	1

* Reservoirs out of service. † October to June 30th.

TABLE 4.—Bacteria.

Averages by Months.

Month.	Reservoirs: Dalecarlia Inlet.	Dalecarlia Outlet.	Georgetown Outlet.	McMillan Park Outlet.	Filtered water.
1905.					
October	.....	.....	.....	210	80
November	.....	.....	.....	150	27
December	.....	15 500	.....	3 800	60
1906.					
January	.....	2 800	.....	1 500	39
February	2 900	4 100	1 800	550	16
March	1 800	1 100	900	650	19
April	3 300	1 700	700	400	22
May	425	210	95	65	17
June	7 900	4 000	325	220	17
July	13 500	600	475	160	26
August	8 700	1 100	1 200	190	14
September	425	250	140	135	14
October	2 300	950	650	270	16
November	1 800	1 100	1 200	220	12
December	6 900	3 800	3 600	700	45

TABLE 4.—(*Continued.*)

Month.	Reservoirs: Dalecarlia Inlet.	Dalecarlia Outlet.	Georgetown Outlet.	McMillan Park Outlet.	Filtered water.
1907.					
January	4 400	2 400	2 200	950	70
February	1 000	950	1 000	700	45
March	11 500	8 300	7 200	3 600	65
April	3 700	2 100	1 400	475	21
May	750	350	325	130	26
June	2 300	1 000	600	100	18
July	2 700	575	350	160	17
August	3 000	275	425	80	17
September	6 200	*	1 900	230	32
October	1 400	*	950	275	27
November	8 900	*	6 600	1 500	27
December	16 000	*	9 600	4 300	190
1908.					
January	11 000	8 700	9 400	3 700	190
February	11 500	6 000	5 000	2 800	75
March	4 600	4 000	2 900	1 300	30
April	700	450	250	120	13
May	9 500	1 100	650	325	17
June	750	120	110	95	12
July	4 900	.....	400	150	8
August	1 600	325	300	100	12
September	325	*	200	80	11
October	375	*	325	140	8
November	550	*	300	200	12
December	600	750	375	170	23
1909.					
January	11 000	2 700	1 600	700	31
February	8 000	3 500	2 400	1 300	60
March	3 800	*	2 600	1 000	39
April	2 200	*	1 400	550	12
May	900	*	350	140	16
June	3 400	*	1 200	170	21
July	550	*	500	250	33
August	400	*	325	55	18
September	325	240	*	70	18
October	350	275	250	130	20
November	600	500	500	180	13
December	21 000	9 100	5 900	4 500	250
1910.					
January	76 000	78 000	88 000	52 000	800
February	45 000	35 500	31 000	17 500	350
March	9 900	7 600	7 400	4 800	80
April	7 900	4 100	3 500	650	29
May	1 230	810	830	448	28
June	3 660	930	800	324	27
Fiscal years:					
1905–06	3 300†	4 300‡	750§	850†	33†
1906–07	4 900	1 900	1 700	650	31
1907–08	6 360	2 700	2 900	1 300	55
1908–09	3 100	2 000	950	400	21
1909–10	14 300	13 900	10 900	6 800	143

* Reservoirs out of service.
† October to June 30th.
‡ December to June 30th.
§ February to June 30th.

TABLE 5.—Results of Tests for *Bacillus Coli*.

Percentage Positive.

Month.	Great Falls, or Dalecarlia Reservoir Inlet.			Dalecarlia Reservoir Outlet.			Georgetown Reservoir.			McMillan Park Reservoir (applied water).			Filtered-water reservoir.		Tap water from various parts of city.	
	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	10 c. c.	1 c. c.
1906.																
*January	55.6	38.9	22.2	69.2	23.1	7.7	56.0	40.0	8.0	55.6	22.2	0	7.2	0	....	....
February	33.3	26.7	6.7	26.1	17.4	8.7	30.4	13.0	4.4	8.3	4.2	0	0	0	....	....
March	50.0	12.5	0	45.5	18.2	0	20.8	8.3	0	18.5	7.4	3.7	0	0	0	0
April	72.2	33.3	16.7	95.5	50.0	4.6	59.1	22.7	4.6	32.0	8.0	0	4.0	0	0	0
May	20.0	8.0	4.0	20.0	12.0	0	7.8	0	0	0	0	0	0	0	0	0
June	57.7	38.5	19.2	40.0	32.0	8.0	50.0	34.6	0	23.1	7.7	3.8	0	0	3.1	0
July	65.0	50.0	5.0	60.0	25.0	10.0	15.0	5.0	5.0	9.5	0	0	4.8	0	....	....
August	84.6	69.2	61.5	88.5	65.4	34.6	80.0	57.7	23.1	63.0	33.3	0	7.4	3.7	11.9	5.1
September	50.0	10.0	0	30.0	10.0	10.0	40.0	10.0	0	32.0	12.0	0	8.0	0	3.1	0
October	60.0	30.0	10.0	55.5	33.3	0	80.0	60.0	20.0	48.1	22.2	3.7	3.7	0	13.0	3.7
November	37.5	0	0	25.0	12.5	12.5	37.5	25.0	0	20.0	12.0	0	8.0	0	0	0
December	55.5	44.5	0	66.7	44.5	22.2	66.7	22.2	0	20.8	8.3	4.2	16.7	8.3	7.5	0
1907.																
January	77.8	33.3	22.2	66.7	33.3	0	55.5	55.5	22.2	69.3	34.6	3.8	19.2	11.5	14.0	0
February	37.5	25.0	0	12.5	0	0	37.5	12.5	0	17.4	4.4	0	0	0	2.9	0
March	87.5	50.0	0	75.0	37.5	0	50.0	25.0	0	30.8	7.7	0	0	0	2.1	0
April	44.5	11.1	11.1	66.7	22.2	11.1	77.8	11.1	11.1	46.1	19.2	3.8	3.8	0	3.2	0
May	91.3	65.2	17.4	88.9	33.3	0	87.5	50.0	12.5	23.1	0	0	0	0	1.4	0
June	80.0	68.0	24.0	87.5	62.5	0	66.7	44.5	11.1	40.0	8.0	0	0	0	0	0
July	42.3	30.8	19.2	25.0	12.5	0	22.2	22.2	0	3.8	0	0	0	0	1.4	1.4
August	48.1	29.6	3.7	33.3	16.7	16.7	36.4	18.2	0	14.8	3.7	0	0	0	0	0
September	62.5	54.1	25.0	....	....	....	41.7	33.3	16.7	16.0	4.0	0	4.0	0	1.7	0
October	51.9	40.8	7.4	....	....	....	58.3	40.0	6.7	38.7	25.8	9.7	6.5	0	12.5	2.8
November	80.0	64.0	24.0	....	....	....	72.7	54.5	0	58.6	17.3	3.5	0	0	4.9	0
December	56.0	48.0	16.0	....	....	....	46.2	38.5	7.7	45.2	29.0	0	19.3	3.2	12.9	4.3
1908.																
January	46.2	30.8	15.4	50.0	12.5	0	33.3	0	0	22.6	9.7	3.2	3.2	0	1.9	1.9
February	12.5	0	0	25.0	0	0	12.5	0	0	0	0	0	0	0	0	0
March	38.5	19.2	7.7	44.4	11.1	0	11.1	0	0	9.7	0	0	0	0	0	0
April	15.4	7.7	0	0	0	0	0	0	0	6.7	3.3	0	0	0	0	0
May	76.0	52.0	40.0	87.5	50.0	12.5	33.3	22.2	0	45.1	16.2	0	0	0	0	0
June	7.7	0	0	0	0	0	11.1	0	0	0	0	0	0	0	0	0
July	26.9	15.4	11.5	22.2	22.2	0	11.1	0	0	6.4	6.4	0	0	0	0	0
August	46.2	26.9	3.9	44.4	33.3	0	62.5	25.0	12.5	12.9	3.2	0	0	0	1.6	0
September	20.0	8.0	4.0	42.9	28.6	1.4	22.2	11.1	0	16.7	10.0	0	0	0	4.3	0
October	18.4	3.7	0	0	0	0	9.1	0	0	9.7	6.4	3.2	0	0	0	0
November	13.0	0	0	28.6	0	0	11.1	0	0	6.6	0	0	0	0	0	0
December	11.5	7.7	3.8	0	0	0	12.5	0	0	3.2	0	0	0	0	0	0
1909.																
January	12.0	8.0	0	30.0	10.0	0	0	0	0	3.2	3.2	0	3.2	0	0	0
February	52.1	47.8	47.8	28.6	14.3	0	37.5	0	0	7.1	3.6	3.6	0	0	3.4	3.4
March	69.4	34.6	3.8	50.0	25.0	0	44.5	11.1	0	32.3	19.4	3.2	6.5	0	2.8	1.4
April	42.3	15.4	3.9	33.3	22.2	11.1	44.4	22.2	11.1	36.6	10.0	0	0	0	0	0
May	88.4	26.1	4.3	50.0	12.5	0	33.3	0	0	12.9	3.2	0	0	0	0	0
June	85.0	60.0	25.0	60.0	40.0	10.0	44.4	33.3	11.1	53.3	20.0	0	0	0	1.4	0

* Presumptive tests.

TABLE 5.—(*Continued.*)

Month.	Great Falls, or Dalecarlia Reservoir Inlet.			Dalecarlia Reservoir Outlet.			Georgetown Reservoir.			McMillan Park Reservoir (applied water).			Filtered-water reservoir.		Tap water from various parts of city.	
	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	0.1 c. c.	10 c. c.	1 c. c.	10 c. c.	1 c. c.
1909.																
July	34.8	8.7	4.4	....	....	....	33.3	11.1	0	25.8	12.9	0	0	0	0	0
August	50.0	15.4	7.7	....	....	....	40.0	10.0	0	22.6	6.5	3.2	0	0	0	0
September	43.5	21.8	8.7	25.0	25.0	12.5	0	0	0	13.3	3.3	0	0	0	0	0
October	36.4	13.6	0	18.2	0	0	0	0	0	3.2	0	0	0	0	0	0
November	4.5	0	0	10.0	0	0	0	0	0	0	0	0	0	0	0	0
December	38.5	23.1	7.7	36.4	36.4	18.2	33.3	22.2	11.1	29.0	22.6	0	9.7	6.5	7.3	1.5
1910.																
January	72.0	48.0	24.0	44.5	33.3	11.1	75.0	25.0	0	61.3	35.5	9.7	25.8	3.2	15.9	3.2
February	47.8	43.5	17.4	63.2	21.1	5.3	40.0	30.0	5.0	32.2	7.1	0	3.6	0	0	0
March	33.3	14.8	0	30.8	11.1	3.7	29.6	22.2	7.4	12.9	3.2	0	0	0	0	0
April	41.7	33.3	20.8	40.0	32.0	16.0	38.5	23.1	15.4	23.3	13.3	0	0	0	0	0
May	47.8	17.4	0	52.0	20.0	0	36.0	16.0	4.0	16.1	12.9	0	0	0	0	0
June	95.5	86.4	31.8	80.8	46.2	19.2	64.0	28.0	8.0	43.3	6.7	0	0	0	1.4	0
Fiscal years:																
1905–06	35.2	19.4	9.3	40.0	23.2	5.2	26.4	14.9	1.7	24.3	8.3	1.8	2.3	1.8	1.3	0
1906–07	61.5	43.6	19.2	57.7	29.2	12.3	51.1	29.8	10.7	32.5	13.0	1.4	4.5	2.1	5.4	1.0
1907–08	44.6	31.3	13.0	32.3	12.3	3.1	34.4	22.1	4.1	22.2	9.4	1.4	2.8	0.3	3.1	0.9
1908–09	38.9	20.2	8.4	30.0	15.0	0	27.4	8.5	2.8	16.7	7.1	0.8	0.8	0	1.2	0.4
1909–10	45.5	26.9	10.1	45.3	24.0	8.8	37.9	19.8	6.2	23.6	10.4	1.1	3.3	0.8	2.2	0.4

TABLE 6.—SUMMARY OF SANITARY CHEMICAL ANALYSES OF WEEKLY SAMPLES, JULY 1ST, 1909, TO JUNE 30TH, 1910.

(Results in Parts per Million.)

(*A*) MAXIMUM.

Reservoirs.	Turbidity.*	Ammonia.			Nitrogen as:		Hardness.	Alkalinity.	Chlorine.
		Free.	Albuminoid.	Total.	Nitrites.	Nitrates.			
Dalecarlia inlet	2 100	0.034	0.264	0.280	0.0070	0.45	120.0	106.0	5.4
Dalecarlia outlet†	200	0.034	0.180	0.206	0.0050	0.70	115.0	105.8	5.7
Georgetown outlet‡	215	0.030	0.182	0.182	0.0060	0.60	115.0	105.0	4.9
McMillan Park outlet.	120	0.028	0.126	0.154	0.0060	0.65	118.0	104.4	4.2
Filtered water	9	0.016	0.078	0.086	0.0010	0.70	119.5	106.3	4.5

(*B*) MINIMUM.

Dalecarlia inlet	7	0.000	0.016	0.016	0.0000	0.00	52.9	39.5	1.0
Dalecarlia outlet†	7	0.000	0.040	0.040	0.0000	0.00	54.3	38.2	0.9
Georgetown outlet‡	7	0.000	0.044	0.044	0.0000	0.00	51.4	40.6	0.7
McMillan Park outlet.	2	0.000	0.010	0.010	0.0010	0.00	51.4	38.5	0.2
Filtered water	0	0.000	0.000	0.000	0.0000	0.00	52.9	40.3	0.4

* Summary of daily samples of water.
† Reservoir out of service from July 1st to September 13th, 1909.
‡ Reservoir out of service from September 10th to October 4th, 1909.

TABLE 6.—(*Continued.*)

(*C*) AVERAGE.

Reservoirs.	Turbidity.*	Ammonia.			Nitrogen as:		Hardness.	Alkalinity.	Chlorine.
		Free.	Albuminoid.	Total.	Nitrites.	Nitrates.			
Dalecarlia inlet.....	86	0.006	0.107	0.113	0.0027	0.19	93.2	81.4	2.9
Dalecarlia outlet†.....	30	0.008	0.106	0.114	0.0023	0.18	95.5	79.5	3.4
Georgetown outlet‡...	29	0.005	0.101	0.106	0.0027	0.18	93.4	80.9	2.9
McMillan Park outlet.	18	0.004	0.077	0.081	0.0027	0.17	94.0	83.0	2.7
Filtered water.....	1	0.002	0.027	0.029	0.0000	0.19	91.9	84.0	2.8

* Summary of daily samples of water.
† Reservoir out of service from July 1st to September 13th, 1909.
‡ Reservoir out of service from September 10th to October 4th, 1909.

No chemical determinations were made during February, March, April, and May, 1910, on account of the rearrangement of the laboratory and equipment.

TABLE 7.—DAILY RESULTS AT PUMPING STATION.

(A)

Month.	Million gallons pumped: To filters.			To sand washers.			Lift to filters.	Pressure at sand-washer pumps, per square inch.	Coal consumed per day, in tons.			Station duty, per 100 lb. of coal consumed.		
	Max.	Min.	Ave.	Max.	Min.	Ave.			Max.	Min.	Ave.	Max.	Min.	Ave.
1909.														
July.....	76.16	57.65	64.05	1.140	0.298	0.730	24.18	110.0	13.4	8.4	10.8	67.8	52.3	61.4
August.....	69.31	54.44	61.42	0.629	0.157	0.441	22.18	110.0	12.4	8.0	10.1	64.2	49.5	56.6
September	66.02	52.82	60.32	0.831	0.207	0.572	22.26	110.0	12.7	8.7	10.5	61.0	48.9	55.1
October.....	78.50	48.12	59.18	0.761	0.060	0.467	21.84	110.0	13.4	8.0	10.3	59.6	49.1	53.6
November.....	64.92	49.83	55.25	0.468	0.141	0.272	20.49	110.0	11.3	7.9	9.2	55.6	45.7	51.1
December.....	67.83	48.32	56.77	0.307	0.039	0.174	20.54	110.0	10.3	8.5	9.5	61.0	45.4	50.4
1910.														
January.....	70.04	51.02	62.49	0.499	0.008	0.156	22.43	110.0	12.7	9.1	10.4	59.6	49.8	54.9
February.....	70.79	55.19	60.28	0.284	0.041	0.173	21.44	112.3	12.3	8.7	10.2	57.4	44.8	51.5
March.....	59.11	51.64	56.04	0.409	0.063	0.171	19.76	120.0	10.5	7.8	9.2	58.2	45.2	49.8
April	66.53	53.79	58.32	0.715	0.167	0.474	20.78	120.0	11.1	8.1	9.7	58.7	47.2	53.7
May	61.93	54.55	57.76	0.525	0.059	0.254	20.30	120.0	10.1	7.4	8.8	60.7	48.1	54.9
June.....	70.49	50.42	58.37	0.281	0.124	0.207	21.19	117.3	12.3	7.4	9.1	60.1	49.9	54.4
Fiscal years:														
1909-10...	78.50	48.12	59.19	1.140	0.008	0.373	21.45	113.3	13.4	7.4	9.8	67.8	44.8	54.0
1905-06*.....	80.59	57.18	66.07	2.062	0.089	0.747	21.71	107.4	14.8	6.4	8.9	79.6	48.2	62.8
1906-07.....	80.29	57.44	66.89	2.120	0.023	0.580	21.60	120.8	15.0	7.0	10.0	71.6	46.5	58.6
1907-08.....	80.38	54.35	64.91	0.735	0.017	0.347	22.20	125.0	12.0	7.2	9.6	70.7	51.3	60.3
1908-09.....	78.93	47.83	61.47	0.875	0.060	0.453	22.52	122.3	13.2	7.0	10.0	74.0	45.7	57.7

* Raw water shut off from city supply on October 5th.

TABLE 7.—(*Continued.*)

(B)

Fiscal year.	Name of coal used.	Cost per ton.	Duty per 100 lb. of coal consumed.	Cost of coal per 1 000 000 ft-lb. of work performed.
1905-06	George's Creek Big Vein	$3.34	62.8	$0.00238
1906-07	" " " "	3.43	58.6	0.00261
1907-08	" " " "	3.75	60.3	0.00278
1908-09	Orenda	3.47	57.7	0.00268
1909-10	"	†3.15	54.0	0.00255

†Corrected for increase or decrease in ash and British thermal units, as determined by United States Geological Survey.

TABLE 8.—AVERAGE CONSUMPTION OF WATER FOR TWENTY-FOUR HOURS, PER MILLION GALLONS.

Month.	Fiscal years.							
	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.
July	59.80	61.50	63.20	69.80	69.18	68.64	71.08	64.05
August	59.00	59.70	67.70	71.40	68.03	67.74	68.14	61.42
September	56.50	61.10	67.90	71.30	69.82	68.93	65.83	60.32
October	58.70	59.10	63.90	68.40	69.14	66.46	65.89	59.18
November	54.70	58.60	62.10	66.10	65.51	61.54	60.06	55.25
December	60.70	60.10	70.30	67.20	65.71	62.29	57.99	56.77
January	60.10	65.30	75.10	65.30	67.62	63.36	57.72	62.49
February	59.30	67.80	86.00	68.70	74.68	68.17	55.42	60.28
March	55.30	60.00	67.60	64.30	64.23	59.63	55.31	56.04
April	55.10	57.20	63.10	62.70	63.45	61.51	58.19	58.32
May	57.70	60.80	66.30	65.60	62.47	62.96	59.25	57.76
June	59.50	62.30	70.60	67.80	63.53	67.96	60.12	58.37
Average	58.03	61.10	68.70	67.40	66.90	64.91	61.47	59.19

The length of runs, depth of scraping, etc., after the scraping or raking, are shown in Tables 10 and 11.

Sand Handling.—For the first three years of operation, the sand was carried from the sand bins in carts and dumped through the numerous manholes of the filters on chutes which could be revolved in various directions, in order to facilitate the spreading of the sand evenly over the surface of the filter.

About a year ago, however, this method was changed, by substituting sand ejectors for the carts. By this method, an ejector is either attached to, or placed directly under, the outlet gate of the sand bin, the gate is opened, and the ejector is started. From this ejector,

the sand is carried back through the line of 4-in. fixed pipe, and one or more lengths of 3-in. hose, to the point of discharge in the filter bed which is being re-sanded.

TABLE 9.

(*A*) NUMBER OF DEATHS FROM TYPHOID FEVER, BY MONTHS, IN THE DISTRICT OF COLUMBIA FOR THE LAST FOURTEEN FISCAL YEARS.

Fiscal year.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Total.
1896-97....	8	15	25	25	18	16	13	4	4	4	6	9	147
1897-98....	10	16	18	10	9	18	8	4	2	9	6	20	130
1898-99....	24	22	22	28	21	16	10	4	7	6	3	6	169
1899-1900..	9	38	30	28	27	26	17	6	8	10	5	12	216
1900-01....	20	41	29	25	28	17	7	2	8	2	4	10	193
1901-02....	16	33	23	21	22	16	19	8	12	9	13	9	206
1902-03....	21	39	25	32	19	20	9	5	9	6	6	3	194
1903-04....	17	26	18	19	8	14	5	5	6	10	8	8	144
1904-05....	16	22	25	14	11	9	11	1	5	7	1	3	125
1905-06*..	15	30	23	26	14	6	6	4	5	4	10	9	152
1906-07....	21	32	21	25	17	4	7	6	4	6	7	2	152
1907-08....	10	18	17	19	11	7	4	1	1	8	8	3	107
1908-09....	15	13	23	17	16	13	16	8	3	8	7	7	146
1909-10....	12	12	17	12	12	2	3	4	7	5	5	4	95
Average..	15.3	25.5	22.9	21.5	16.6	13.1	9.6	4.4	5.8	6.7	6.4	7.5	155.4

(*B*) NUMBER OF DEATHS FROM TYPHOID FEVER REDUCED TO DEATH RATES PER 100 000 INHABITANTS PER YEAR.

Fiscal Year.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Annual death rate.
1896-97.....	35	65	109	109	78	70	56	17	17	17	26	39	53
1897-98.....	43	69	78	43	39	78	34	17	8	38	25	85	46
1898 99.....	102	93	93	119	89	68	42	17	29	25	12	25	59
1899-1900....	37	158	125	116	112	108	69	24	33	41	20	49	74
1900-01.....	82	167	118	102	114	69	28	8	32	8	16	40	65
1901-02.....	64	132	112	84	88	64	75	31	47	35	51	35	68
1902-03.....	83	153	98	126	75	79	35	19	35	23	23	12	63
1903-04.....	66	100	69	73	31	54	19	19	23	38	30	30	46
1904-05.....	61	83	95	53	42	34	41	4	19	26	4	11	39
1905-06.....	56	111	85	97	52	22	22	15	18	15	36	33	47
1906-07.....	69	105	69	82	56	13	24	20	13	20	24	7	42
1907-08.....	35	64	60	67	39	25	14	4	4	28	28	11	32
1908-09.....	53	45	80	60	56	45	56	28	10	28	24	24	43
1909-10.....	42	42	60	42	42	7	11	14	24	17	17	14	28
Average monthly death rate.	59	99	89	84	65	53	38	24	22	26	24	30	..

* Filtered water supplied since October, 1905.

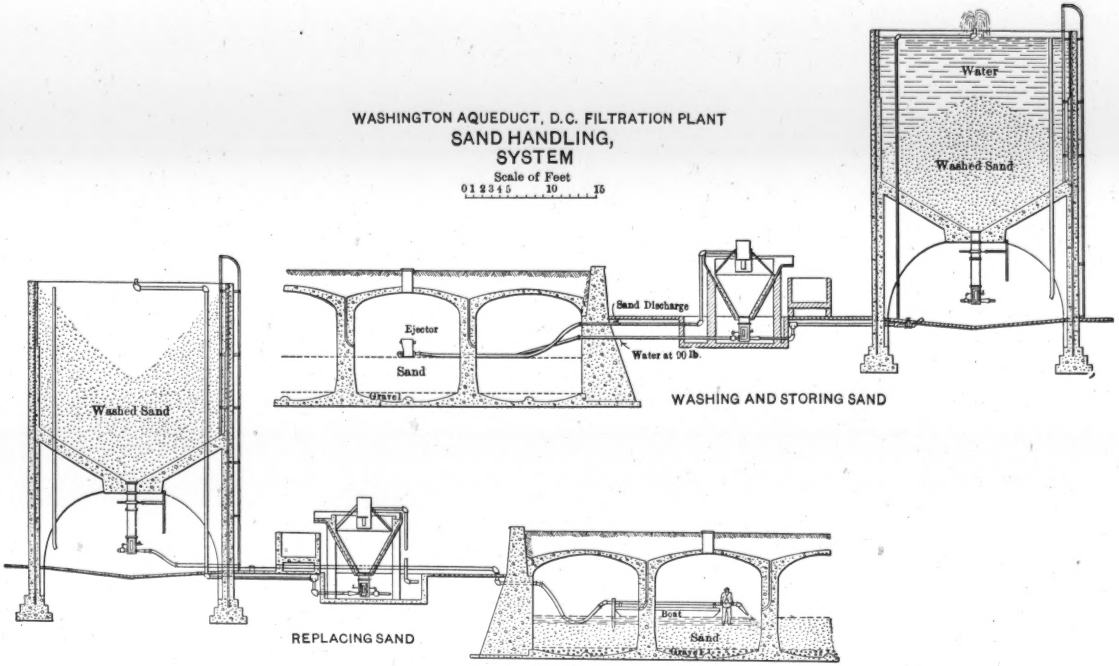

WASHINGTON AQUEDUCT, D.C. FILTRATION PLANT
SAND HANDLING,
SYSTEM
Scale of Feet
0 1 2 3 4 5 10 15
Water
Washed Sand
Sand Discharge
Ejector
Sand
Water at 90 lb.
Gravel
WASHING AND STORING SAND
Washed Sand
REPLACING SAND
Boat
Sand
Gravel

FIG. 3.

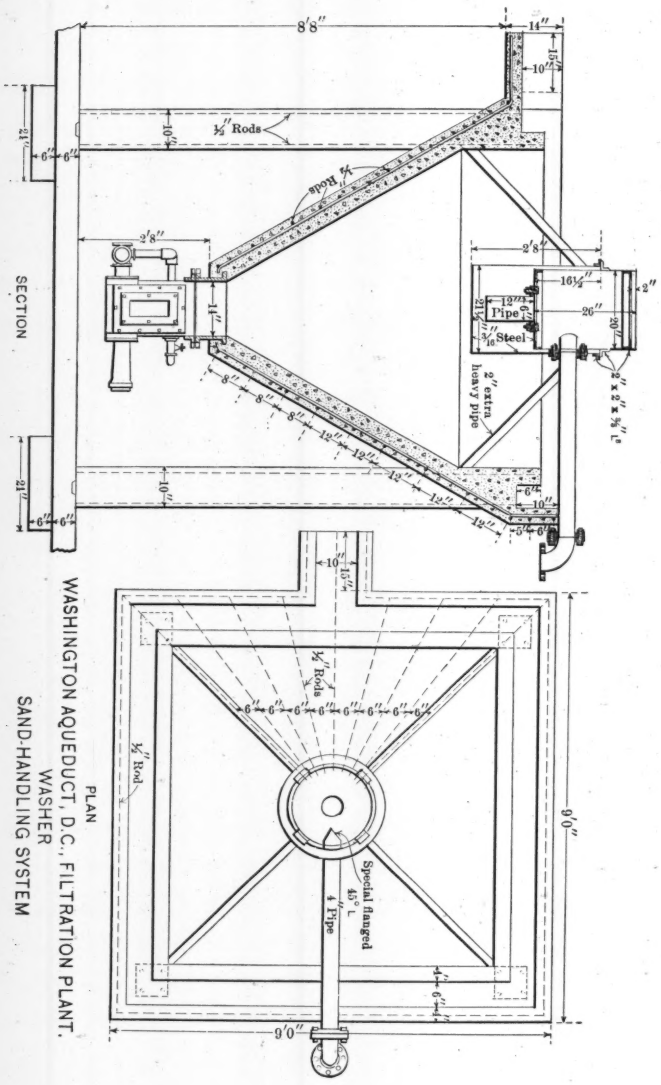


Fig. 4.

WASHINGTON AQUEDUCT, D.C., FILTRATION PLANT.
WASHER
SAND-HANDLING SYSTEM

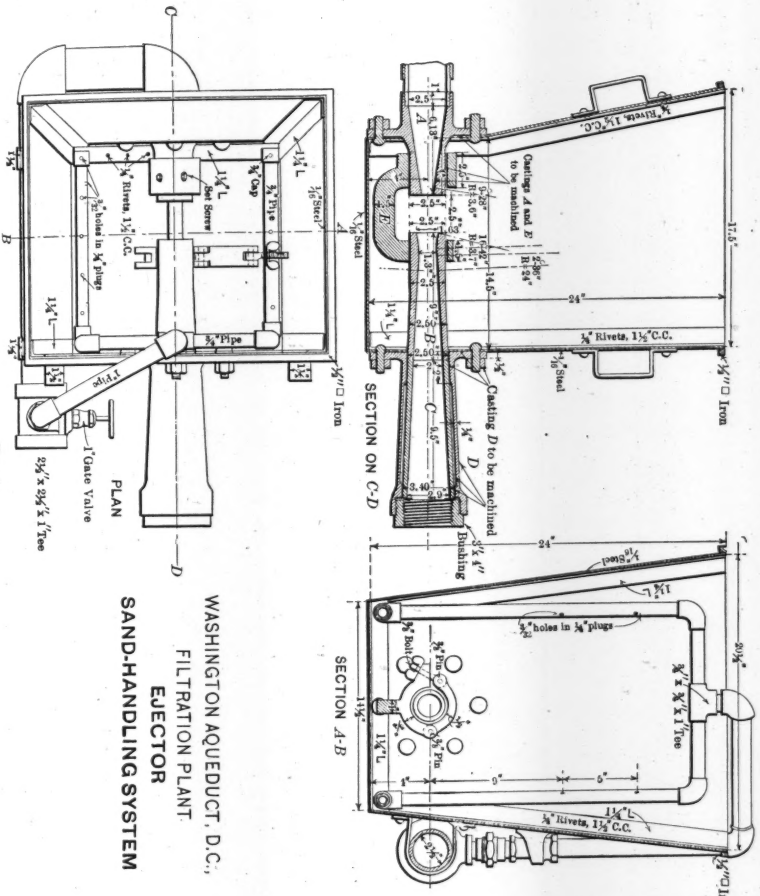

PLAN
SECTION ON C-D
SECTION A-B
WASHINGTON AQUEDUCT, D.C.,
FILTRATION PLANT.
EJECTOR
SAND-HANDLING SYSTEM

FIG. 5.

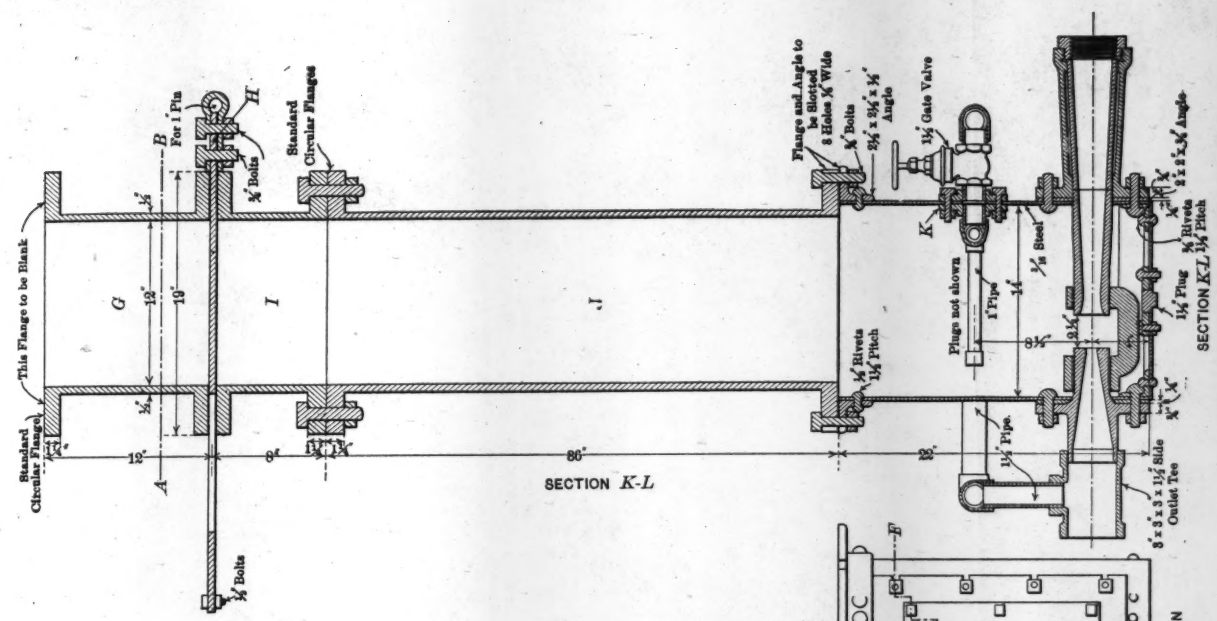
TABLE 10.—PERIODS OF OPERATION, AND QUANTITIES FILTERED.

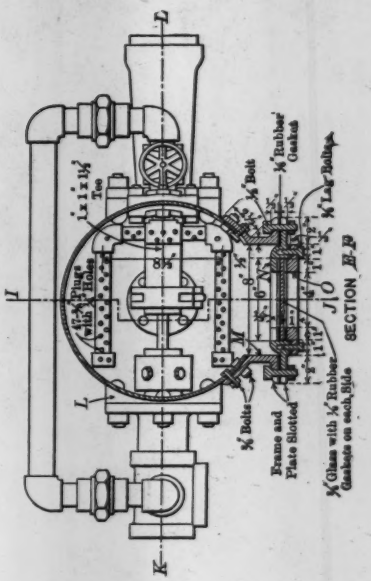
Month.	Number of filter runs ended after:		Number of days since previous:						Million gallons filtered since previous:					
			Scraping.			Raking.			Scraping.			Raking.		
	Scraping.	Raking.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
1909.														
July	14	0	89	44	67.4	0	0	0	229.01	106.27	163.289	0	0	0
August	8	0	74	51	60.4	0	0	0	175.54	124.94	152.581	0	0	0
September	13	0	98	53	68.3	0	0	0	237.52	114.37	161.702	0	0	0
October	18	5	81	32	59.9	43	33	39.4	206.09	78.78	132.359	96.50	71.51	82.708
November	8	2	79	44	53.4	47	37	42.0	168.19	82.32	112.608	99.00	90.23	94.615
December	3	4	62	61	61.3	63	50	57.3	135.77	128.33	132.647	144.35	106.11	125.940
1910.														
January	9	4	95	79	88.0	88	72	77.0	204.38	146.58	178.461	189.48	152.33	170.735
February	1	4	99	99	99.0	93	51	71.0	205.73	205.73	205.730	192.98	118.85	158.890
March	3	4	120	110	113.7	108	101	104.3	275.96	257.36	265.493	249.68	224.49	238.993
April	10	12	126	62	84.8	129	21	65.3	295.96	104.13	181.972	307.57	45.22	142.448
May	3	2	86	38	69.7	55	32	43.5	186.64	81.66	150.230	102.15	69.79	85.978
June	13	2	100	61	79.7	129	78	103.5	213.70	130.85	171.059	181.25	167.84	174.540
Year 1909-10	103	39	126	32	71.1	129	21	66.6	295.96	81.66	159.151	307.57	45.22	143.882
Fiscal years:														
1905-06	71	0	195	38	91.1	0	0	0	497.45	116.66	240.379	0	0	0
1906-07	101	4	199	24	77.0	32	14	21.7	466.12	69.76	220.693	103.28	32.13	76.870
1907-08	143	77	180	11	54.9	63	7	28.6	477.19	28.20	146.912	165.25	17.08	75.775
1908-09	128	50	135	11	49.9	93	13	34.2	298.08	39.26	125.617	244.19	41.41	88.439

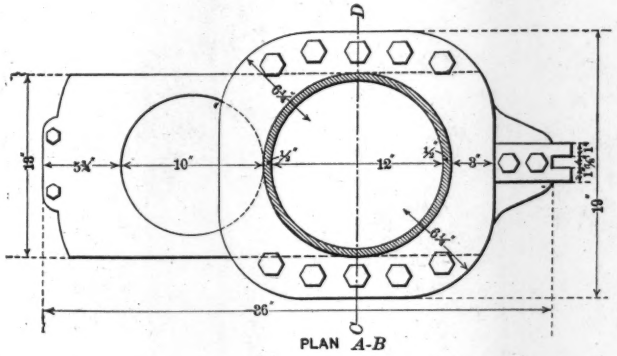
In re-sanding a filter, it is first filled with water to the proposed depth of the sand layer. The outlet end of the hose is connected to a 3-in. pipe which is supported on a boat, and the sand is discharged through this pipe at the point required. Work is first begun at the far end of the filter, and it is gradually filled by swinging the boat from side to side and backing it by degrees to the front end.

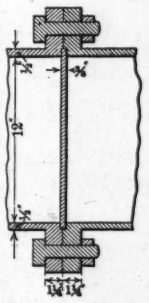
At first it was feared that a small quantity of mud would be deposited on the surface of the old sand, and that this mud would ultimately cause subsurface clogging. For this reason, when this method was first adopted, a man was required to rake the sand very thoroughly in front of the discharge. Later, it was found that by giving the end of the discharge pipe a slope of about 45° downward from the horizontal, the force of the current of sand and water could be depended on to cut the old surface of sand to any required depth, and move it ahead together with the new sand, thus completely breaking up the possible mud layer between the old and new sand layers. After having

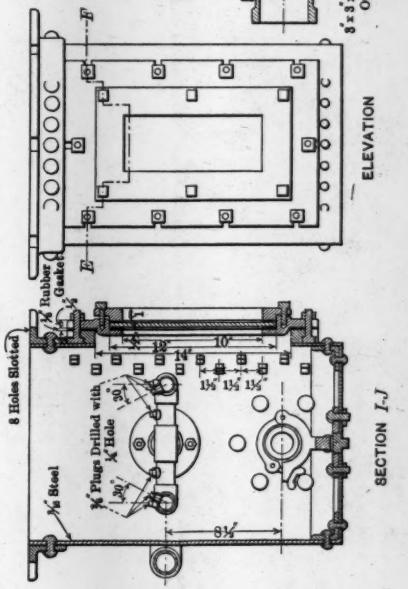
PLATE I.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXII, No. 1191.
HARDY ON
WASHINGTON WATER FILTRATION PLANT.











DETAIL OF GATE

WASHINGTON AQUEDUCT, D.C.
FILTRATION PLANT
INJECTOR
SAND-HANDLING SYSTEM

used this method almost exclusively for 15 months, in which time eleven filters have been re-sanded, and 24 531 cu. yd. of sand have been replaced, there seems to be no indication of an increased initial loss of head. The sand is very compact, and has no apparent tendency to separate into different sizes. The general appearance is similar to that of very fine sand on the seashore. The filters re-sanded in this way have been considerably more efficient than those in which the sand was replaced with carts, and as yet, no harmful results have been noted. The rate at which the sand is replaced is shown in Table 12, and the cost of labor for sand handling is given in detail in Table 14, which shows that quite a perceptible saving has been effected by the hydraulic method.

The figures showing the cost for sand handling do not include any charge for the quantity of water used, that item having been carried on the pumping-station account.

TABLE 11.—QUANTITIES OF SAND REMOVED.

Month.	No. of filters scraped when last treatment was:		Cubic yards when last treatment was:						Depth, in inches, when last treatment was:					
			Scraping.			Raking.			Scraping.			Raking.		
	Scraping.	Raking.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
1909.														
July	14	0	338	121	190.6	0	0	0	2.51	0.90	1.415	0	0	0
August	8	0	356	149	218.5	0	0	0	2.65	1.11	1.631	0	0	0
September	8	0	524	97	178.6	0	0	0	3.90	0.72	1.330	0	0	0
October	9	5	150	93	115.8	301	121	169.0	1.12	0.69	0.862	2.24	0.90	1.256
November	2	2	134	88	111.0	132	81	106.5	1.00	0.65	0.825	0.98	0.60	0.790
December	0	2	0	0	0	133	126	129.5	0	0	0	0.99	0.94	0.965
1910.														
January	2	4	155	112	133.5	195	121	147.8	1.15	0.83	0.990	1.45	0.90	1.100
February	0	4	0	0	0	390	160	225.8	0	0	0	2.90	1.19	1.678
March	1	4	489	489	489.0	262	179	214.3	3.64	3.64	3.640	1.95	1.33	1.593
April	4	12	172	84	119.3	230	146	178.8	1.28	0.62	0.885	1.71	1.09	1.331
May	1	2	320	320	320.0	249	241	245.0	2.38	2.38	2.380	1.85	1.79	1.820
June	0	2	0	0	0	203	190	196.5	0	0	0	1.51	1.41	1.460
Year 1909-10	49	37	524	84	176.7	390	81	181.0	3.90	0.62	1.314	2.90	0.60	1.373
Fiscal Years:														
1905-06	71	0	600	71	250.0	0	0	0	4.47	0.53	1.799	0	0	0
1906-07	94	2	536	52	259.0	398	276	337.0	4.00	0.56	1.931	2.95	2.05	2.500
1907-08	81	53	527	46	190.2	411	35	118.4	3.92	0.21	1.507	3.06	0.21	0.881
1908-09	92	50	580	55	169.5	472	81	177.5	4.31	0.41	1.259	3.51	0.60	1.317

TABLE 12.—Rates of Sand Handling.

Date.	Sand removed from filters.			Sand replaced in filters.		
	Ejector hours.	Cubic yards of sand removed.	Average rate, in cubic yards per hour.	Ejector hours.	Cubic yards of sand removed.	Average rate, in cubic yards per hour.
1906.						
April	49	253	5.2	.....	.....	.....
May	380	2 511	6.6	.....	.....	.....
June	567	3 280	5.8	.....	.....	.....
July	931	5 376	5.8	.....	.....	.....
August	105	533	5.1	.....	.....	.....
September	315	1 892	6.0	.....	.....	.....
October	1 067	6 173	5.8	.....	.....	.....
November	168	935	5.6	.....	.....	.....
December	208	1 073	5.3	.....	.....	.....
1907.						
January	399	2 974	7.3	.....	.....	.....
February	140	1 139	8.1	.....	.....	.....
March	115	878	7.6	.....	.....	.....
April	427	3 103	7.3	.....	.....	.....
May	133	939	7.0	.....	.....	.....
June	105	674	6.4	.....	.....	.....
July	7	46	6.6	.....	.....	.....
August	90	574	6.4	.....	.....	.....
September	306	1 996	6.5	.....	.....	.....
October	273	1 701	6.2	.....	.....	.....
November	202	1 258	6.3	.....	.....	.....
December	364	2 138	5.9	.....	.....	.....
1908.						
January	546	3 708	6.8	.....	.....	.....
February	98	776	7.9	.....	.....	.....
March	315	2 832	9.0	.....	.....	.....
April	469	3 775	8.1	.....	.....	.....
May	182	1 414	7.8	.....	.....	.....
June	280	2 057	7.4	.....	.....	.....
July	280½	2 683	9.6	.....	.....	.....
August	327½	2 808	8.6	.....	.....	.....
September	402	3 371	8.4	.....	.....	.....
October	308	2 696	8.7	.....	.....	.....
November	47½	333	7.0	.....	.....	.....
December	153¾	1 268	8.3	.....	.....	.....
1909.						
January	119½	1 055	8.8	.....	.....	.....
February	161½	1 479	9.2	.....	.....	.....
March	144	1 465	10.2	.....	.....	.....
April	214¾	2 260	10.5	188	2 405	12.8
May	219¾	2 223	10.1	190	2 196	11.5
June	355	3 096	8.7	243	3 054	12.6
July	312½	2 707	8.7	425½	4 050	9.5
August	218¾	1 955	9.0	64½	620	9.6
September	172½	1 360	7.9	408	2 842	7.0
October	203	1 870	9.2	261¼	2 350	9.0
November	54	397	7.4	0	0	.....
December	62	382	6.2	0	0	.....
1910.						
January	104	703	6.8	0	0	.....
February	106½	1 058	9.9	28¼	371	13.1
March	98	985	10.0	72	1 008	14.0
April	268¾	2 852	10.7	134¼	2 159	16.1
May	58¾	693	11.8	171¾	3 042	17.7
June	58¾	642	10.9	9¾	166	17.0

The cost for pumping water for sand handling, including all labor, materials, and repairs, amounts to $0.06 per cu. yd. of sand ejected and washed, and $0.03 per cu. yd. for replacing.

In addition to the water used for carrying the sand which is being replaced, it is customary to keep a slight upward flow in the filter, thus using about 500 000 gal. of filtered water per day for this purpose. Assuming the value of this water to be the total cost for pumping, filtering, etc., or $3.80 per 1 000 000 gal., the cost per cubic yard of sand replaced would be about $0.02 when one ejector is used, and $0.01 when two are in operation.

It is not considered absolutely necessary to have an upward flow of water in the filter which is being re-sanded, and it is not always done. It was used, however, as an additional safeguard against the formation of a stratum of mud between the old and new layers of sand while the hydraulic method was in an experimental stage.

The quantities of sand removed from the filters per scraping and the rates of sand handling are shown in Tables 11 and 12.

Cost of Operation.—It is frequently difficult to compare the relative cost of corresponding items for different plants, because of the different methods of dividing the cost and the varying opinions of the officials as to what should properly be charged to each item.

In order that the data may be in sufficient detail to permit it to be rearranged to compare with other plants, a list of employees and charges for supplies is given in Table 13. This list accounts for the entire appropriation for the care and maintenance of the filtration plant, including pumping the water to the filters, parking and caring for the grounds, buildings, roads, sidewalks, etc. The cost for the various items per million gallons pumped to the filters is shown in Table 14, and the cost per cubic yard of sand handled in Table 15.

Preliminary Treatment.—Before the present filtration plant was designed, Rudolph Hering, George W. Fuller, and Allen Hazen, Members, Am. Soc. C. E., made an investigation and report. This report was dated February 18th, 1901, and contained the following paragraph:

"In consideration of the full evidence, we recommend the construction of a complete system of slow or sand filters, with such auxiliary works as may be necessary for preliminary sedimentation, and the use of a coagulant for part of the time. There is no reason to believe that

the use of this coagulant will in any degree affect the wholesomeness of the water."

Notwithstanding this opinion, considerable prejudice existed among the citizens of Washington against the use of a coagulant, and, as finally passed, the bill providing for the construction of the filters did not include an appropriation for the coagulant.

TABLE 13.—List of Employees, Rates of Pay, and Approximate Cost for Supplies.

1 Superintendent	$3 000.00
1 Chief Chemist and Assistant Superintendent	2 100.00
1 First Assistant Chemist	1 500.00
1 Second Assistant Chemist	1 000.00
1 Stenographer and Clerk	1 200.00
1 Surveyor	1 200.00
1 Laboratory Helper	720.00
1 Janitor	600.00
1 Chief Steam Engineer	1 800.00
1 First Assistant Steam Engineer	1 440.00
1 Second Assistant Steam Engineer	1 080.00
3 Oilers, at $900 each	2 700.00
3 Firemen, at $900 each	2 700.00
3 Laborers, at $540 each	1 620.00
1 Filter Foreman	1 200.00
2 Foremen, at $900 each	1 800.00
1 Timekeeper	900.00
3 Watchmen and Gauge Tenders, at $900 each	2 700.00
1 Machinist	1 140.00
1 Blacksmith	900.00
1 Storekeeper	900.00
1 Painter	900.00
1 Mechanic	900.00
1 Electrician	900.00
4 Skilled Laborers at $600 each	2 400.00
1 Watchman and Special Officer	900.00
1 Recorder	720.00
27 Laborers, at $1.50 per day for 300 days	12 150.00
3 Teams, at $2.00 per day for 200 days	1 200.00
Laboratory and office supplies	2 700.00
Filter supplies, tools, hose, repair of roads, parks, shrubs, etc	8 820.00
Pumping station supplies, oil, waste, packing, repairs, etc	3 570.00
3 600 tons of coal, at $3.15 per ton	11 340.00
Charges in U. S. Engineer Office, labor	2 900.00
" " " " " materials	400.00
Total	$82 000.00

The results obtained from operating the filters being such as to justify the conclusions in the report referred to, an experimental plant was constructed for the purpose of studying the efficiency of various methods of preliminary treatment of the water. This plant consisted of three cylindrical concrete filter tanks, each 10 ft. in diameter. These tanks were filled with the layers of gravel and sand necessary to make them represent as accurately as possible the large slow sand units of the main filtration plant. Means were also provided for giving a preliminary treatment to the water supplying each of these experimental slow sand filters. In two cases, the preliminary treatment was rapid filtration, while the third consisted of sedimentation and

TABLE 14.—Cost per Million Gallons Filtered.

(*A*) Labor.

Month.	Office and laboratory.	Pumping station.	Filter operations:		Parking (care of grounds), etc.	Experimental filters.	Main office.	Total.
			Sand handling.	Repairs, etc.				
1909.								
July	$0.73	$0.57	$0.86	.....	$0.31	.....	$0.15	$2.62
August	0.75	0.64	0.59	.....	0.71	.....	0.14	2.83
September	0.83	0.67	0.80	.....	0.51	.....	0.17	2.98
October	0.72	0.66	0.73	.....	0.34	.....	0.18	2.53
November	0.87	0.76	0.42	.....	0.38	.....	0.18	2.61
December	0.90	0.69	0.27	.....	0.40	.....	0.12	2.38
1910.								
January	0.81	0.63	0.33	.....	0.14	.....	0.10	2.01
February	0.94	0.74	0.35	$0.07	0.11	.....	0.16	2.37
March	0.92	0.81	0.30	0.07	0.18	.....	0.13	2.41
April	0.93	0.88	0.49	0.03	0.36	.....	0.13	2.77
May	0.86	0.72	0.36	0.03	0.55	.....	0.18	2.70
June	0.88	0.67	0.38	.....	0.38	.....	0.12	2.43
Average	0.84	0.70	0.27	*0.25	0.36	.....	0.14	2.56
Fiscal years:								
1905–1906	0.45	0.45	0.47	0.02	0.01	.....	0.09	1.49
1906–1907	0.57	0.57	0.58	0.21	0.07	$0.03	0.04	2.07
1907–1908	0.70	0.59	0.42	0.32	0.15	0.09	0.09	2.36
1908–1909	0.72	0.61	0.41	0.34	0.22	0.01	0.13	2.44

(*B*) Materials.

1909.								
July	.....	.....	$0.01	.....	.....	.....	.....	$0.01
August	$0.01	.....	.....	.....	$0.07	.....	$0.01	0.09
September	0.05	$0.31	0.04	.....	0.01	.....	0.03	0.44
October	0.08	0.11	0.13	.....	0.46	.....	0.02	0.80
November	0.13	0.78	0.10	.....	0.34	.....	0.02	1.37
December	0.03	0.17	0.05	.....	0.01	.....	0.05	0.31
1910.								
January	0.12	0.74	0.14	.....	0.01	.....	.....	1.01
February	0.07	1.88	0.18	.....	0.01	.....	0.01	2.15
March	0.26	0.28	0.01	.....	.....	.....	.....	0.55
April	0.18	1.22	0.10	.....	0.29	.....	0.02	1.81
May	0.06	0.72	0.02	.....	0.11	.....	0.02	0.93
June	0.54	2.23	.....	$†2.16	0.46	.....	0.04	5.43
Average	0.13	0.69	0.02	‡0.21	0.17	.....	0.02	1.24
Fiscal years:								
1905–1906	0.04	0.59	0.02	.....	.....	.....	.....	0.65
1906–1907	0.03	0.67	0.08	0.20	0.02	.....	.....	1.00
1907–1908	0.05	0.54	0.04	0.07	0.06	.....	0.01	0.77
1908–1909	0.10	0.69	0.05	0.18	0.18	.....	0.02	1.22

* $0.02 for new sand-handling system.
† $2.02 " " "
‡ $0.16 " " "

TABLE 14.—(*Continued.*)

(*C*) TOTALS.

Month.	Office and laboratory.	Pumping station.	Filter operations:		Parking (care of grounds), etc.	Experimental filters.	Main office.	Total.
			Sand handling.	Repairs, etc.				
1909.								
July	$0.73	$0.57	$0.87	.....	$0.31	.....	$0.15	$2.63
August	0.76	0.64	0.59	.....	0.78	.....	0.15	2.92
September	0.88	0.98	0.84	.....	0.52	.....	0.20	3.42
October	0.80	0.77	0.86	.....	0.80	.....	0.10	3.33
November	1.00	1.54	0.52	.....	0.72	.....	0.20	3.98
December	0.93	0.86	0.32	.....	0.41	.....	0.17	2.69
1910.								
January	0.93	1.37	0.47	.....	0.15	.....	0.10	3.02
February	1.01	2.62	0.53	$0.07	0.12	.....	0.17	4.52
March	1.18	1.09	0.31	0.07	0.18	.....	0.13	2.96
April	1.11	2.05	0.59	0.03	0.65	.....	0.15	4.58
May	0.92	1.44	0.38	0.03	0.66	.....	0.20	3.63
June	1.42	2.90	0.38	2.16	0.84	.....	0.16	7.86
Average	0.97	1.39	0.29	0.46	0.53	.....	0.16	3.80
Fiscal years:								
1905–1906	0.49	1.04	0.49	0.02	0.01	.....	0.09	2.14
1906–1907	0.60	1.24	0.66	0.41	0.09	$0.03	0.04	3.07
1907–1908	0.75	1.13	0.46	0.39	0.21	0.09	0.10	3.13
1908–1909	0.82	1.30	0.46	0.52	0.40	0.01	0.15	3.66

coagulation. The sedimentation tank was of sufficient size, when compared with the area of the experimental slow sand filter, to represent the Georgetown and McMillan Park Reservoirs when used in connection with the large filters. The first preliminary filter was very similar in construction and operation to a mechanical filter. The sand for this filter was taken from the main filters, and, consequently, was finer than is generally used in mechanical filters. The second preliminary filter was a Maignen scrubber. It consisted of a cylindrical concrete tank, 4 ft. in diameter and 8½ ft. deep, which contained 12 in. of cobble-stones on the bottom, then, successively, 12 in. of egg-size coke, 12 in. of stove-size coke, 24 in. of nut-size coke, and 24 in. of sponge clippings as the final or top layer.

The two preliminary filters were operated at a rate of about 50 000 000 gal. per acre per day, and the three slow sand filters at rates of from 3 000 000 to 4 000 000 gal. per day.

This plant was put in service during the early part of February, 1907, and was kept in practically continuous operation until the end of July, 1908.

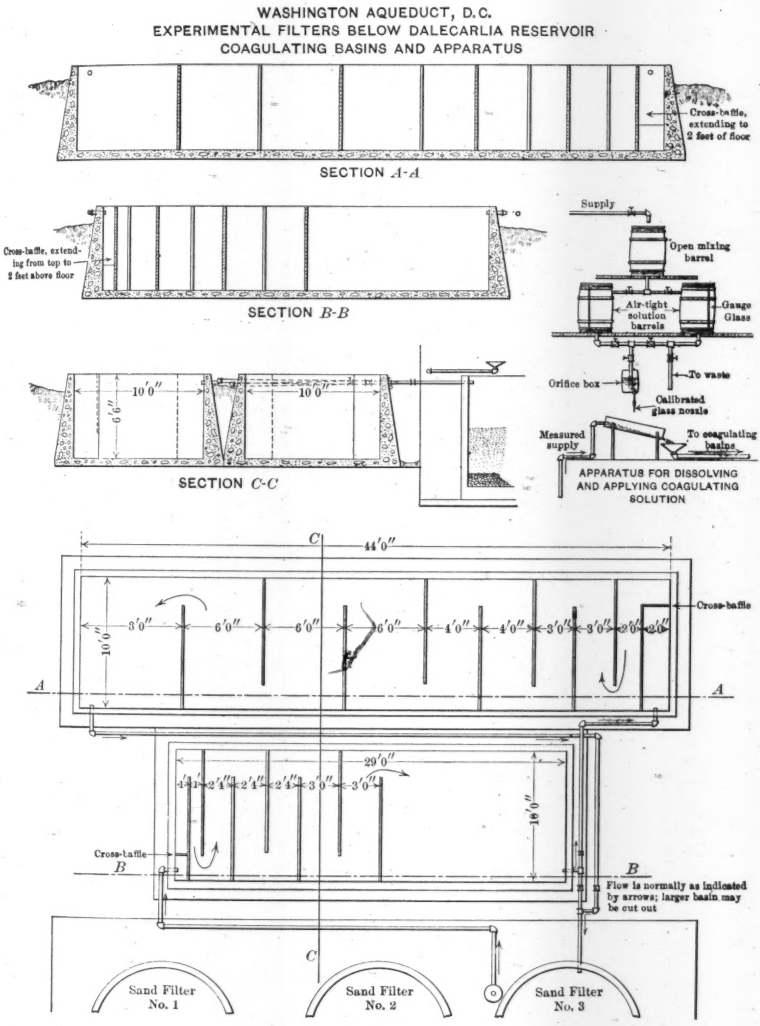

WASHINGTON AQUEDUCT, D.C.
EXPERIMENTAL FILTERS BELOW DALECARLIA RESERVOIR
COAGULATING BASINS AND APPARATUS
Cross-baffle, extending to 2 feet of floor
SECTION A-A
Cross-baffle, extending from top to 2 feet above floor
SECTION B-B
10'0"
10'0"
6'0"
SECTION C-C
Supply
Open mixing barrel
Air-tight solution barrels
Gauge Glass
Orifice box
To waste
Calibrated glass nozzle
Measured supply
To coagulating basins
APPARATUS FOR DISSOLVING AND APPLYING COAGULATING SOLUTION
C
44'0"
Cross-baffle
10'0"
3'0"
6'0"
6'0"
6'0"
4'0"
4'0"
3'0"
3'0"
2'0"
2'0"
A
A
29'0"
1'1"
2'4"
2'4"
2'4"
3'0"
3'0"
16'0"
Cross-baffle
B
B
Flow is normally as indicated by arrows; larger basin may be cut out
C
Sand Filter No. 1
Sand Filter No. 2
Sand Filter No. 3

FIG. 6.

TABLE 15.—AVERAGE COST FOR LABOR FOR SAND HANDLING.

(*A*) PER MILLION GALLONS PUMPED TO FILTER.

Month.	Scraping.	Ejecting.	Washing.	Smoothing.	Raking.	Re-sanding.	Total.
1909.							
July	$0.10	$0.21	$0.03	$0.02	....	$0.21	$0.57
August	0.07	0.16	0.03	0.01	....	0.04	0.31
September	0.05	0.13	0.02	0.01	$0.01	0.27	0.49
October	0.06	0.15	0.03	0.01	0.02	0.12	0.39
November	0.02	0.06	....	....	0.02	....	0.10
December	0.02	0.04	0.01	....	0.01	0.01	0.09
1910.							
January	0.04	0.07	....	0.01	0.02	....	0.14
February	0.04	0.10	....	0.01	....	0.02	0.17
March	0.04	0.06	....	0.01	0.01	0.05	0.17
April	0.10	0.15	0.04	0.01	0.02	0.06	0.38
May	0.02	0.03	0.01	....	0.01	0.11	0.18
June	0.02	0.04	....	....	0.02	0.01	0.09
Average	0.05	0.10	0.01	0.01	0.01	0.08	0.26
Fiscal years:							
1905-06	0.06	0.29	0.02	0.06	....	0.04	0.47
1906-07	0.07	0.20	0.05	0.02	....	0.24	0.58
1907-08	0.09	0.14	0.03	0.01	0.02	0.13	0.42
1908-09	0.07	0.15	0.03	0.01	0.01	0.14	0.41

(*B*) PER CUBIC YARD OF SAND.

1909.							
July	$0.08	$0.15	$0.03	$0.01	....	$0.10	$0.37
August	0.07	0.15	0.03	0.01	....	0.11	0.37
September	0.07	0.17	0.03	0.01	....	0.17	0.45
October	0.06	0.15	0.03	0.01	....	0.09	0.34
November	0.10	0.23	0.02	0.02	....	....	0.37
December	0.12	0.25	0.04	0.02	....	0.08	0.51
1910.							
January	0.10	0.19	....	0.02	....	....	0.31
February	0.07	0.15	....	0.01	....	0.09	0.32
March	0.06	0.11	....	0.02	....	0.08	0.27
April	0.07	0.09	0.03	0.01	....	0.05	0.25
May	0.06	0.09	0.03	0.01	....	0.06	0.25
June	0.06	0.12	....	0.01	....	0.10	0.29
Average	0.07	0.14	0.02	0.01	....	0.10	0.34
Fiscal years:							
1905-06	0.07	0.35	0.04	0.07	....	0.14	0.67
1906-07	0.06	0.19	0.03	0.02	....	0.17	0.47
1907-08	0.09	0.15	0.03	0.01	....	0.14	0.42
1908-09	0.06	0.14	0.03	0.01	....	0.13	0.37

For convenience in referring to the different systems, the combined rapid and slow sand filter will be designated as Filter Plant No. 1, the combined Maignen scrubber and slow sand filter as Filter Plant No. 2, and the combined coagulating basin and slow sand basin as Filter Plant No. 3.

The length of run of Filter Plant No. 1 was relatively long at

first. The rapid rate of filtration, however, tended to carry the clay, which was suspended in the applied water, to a considerable depth in the filtering material, so that the runs gradually decreased in length until they were reduced to about three days. Unfortunately, it was necessary to use unfiltered water for washing, which, together with the great penetration from the applied water, finally made it necessary to remove all the filtering materials, and wash them.

Although this preliminary filter was operated at a high rate, its efficiency was quite satisfactory. In fact, at times when the applied water was comparatively good, very little work was left for the slow sand filter. At times of high turbidity, however, some of the exceedingly fine mud in the applied water passed through this filter, as well as the slow sand filter connected with it, and it proved to be absolutely impossible to produce a clear effluent at all times with this combination.

Filter Plant No. 2 proved more economical and convenient in operation, but somewhat less efficient than Filter Plant No. 1. Neither filter could be depended on to give a clear effluent when the applied water was turbid.

In the operation of Filter Plant No. 3, sulphate of alumina was used when the applied water contained too much turbidity to be treated satisfactorily by slow sand filters.

When the water was comparatively clear, either one of the three systems, or slow sand filtration alone, was entirely satisfactory. At times of high turbidity, however, Filter Plant No. 3 was the only one which could be depended on to produce a clear effluent.

A fair comparison between the results of the three systems when treating turbid water in January, 1908, is given in Table 16.

Table 16 shows very clearly that neither Filter Plant No. 1 nor No. 2 would prove at all satisfactory when treating turbid water, while No. 3 could be depended on under all conditions. The results of operation are shown in detail in Tables 17, 18, and 19. It will be noticed in Table 17, that on March 10th, 1908, Filter Plant No. 1 was put out of service and a Puech system of preliminary filters was substituted for it.

The Puech preliminary filters consisted of five units containing gravel of varying sizes through which the water was filtered successively before it was finally applied to the final slow sand filter. A general idea of this system may be obtained by referring to Fig. 8.

TABLE 16.—Turbidity Results with Experimental Filters, During Period of High Turbidity, January, 1908.

Date.	Raw water.	Filter No. 1.		Filter No. 2.		Filter No. 3.	
		Effluent, preliminary filter.	Effluent, sand filter.	Effluent, preliminary filter.	Effluent, sand filter.	Effluent, coagulant basin.	Effluent, sand filter.
January 12th...	40	10	1	12	1	2	0
" 13th...	110	45	2	51	2	2	0
" 14th...	210	95	3	113	4	2	0
" 15th...	325	190	12	222	15	3	0
" 16th...	360	210	37	247	42	5	0
" 17th...	242	122	24	147	26	6	0
" 18th...	137	..	..	73	7	6	0
" 19th...	117	40	12	cleaning	..	5	0
" 20th...	72	31	6	sand filter	..	cleaning.	0
" 21st...	55	20	4	25	4	sand	..
" 22d....	49	17	3	21	4	filter	..
" 23d....	40	12	3	15	3	3	0
" 24th...	40	11	3	13	3	3	0

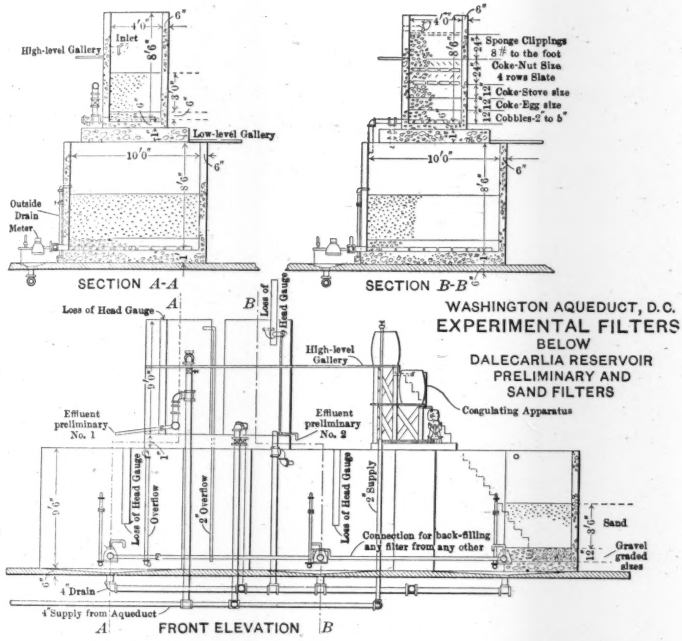
It is unfortunate that this system was not in operation in January, 1908, when the water was cold and turbid. The results, however, indicate that it would be no more successful than either Filter Plant No. 1 or No. 2.

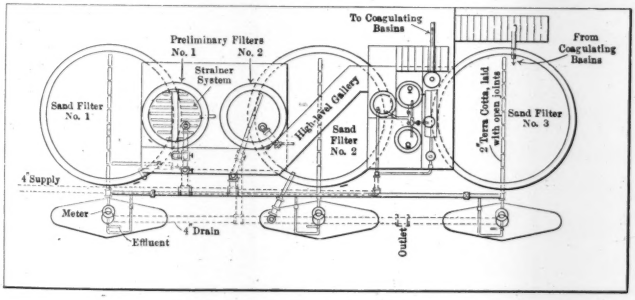
Experimental Rate Studies.—In September, 1908, an experimental plant consisting of six small filters was put in operation. The object of these experiments was to study the relative efficiencies and cost for the operation of slow sand filters when operated at different rates.

The units of the plant consisted of cylindrical galvanized-iron tanks 4 ft. in diameter and 9 ft. high. The filter sand in these tanks was taken from the supply for the main filters. It was supported on gravel layers and supplied with under-drains of suitable sizes for the proposed rate of flow in each case.

The units of the experimental plant were designated as Nos. 1, 2, 3, 4, 5, and 6, and it was the original intention to operate them at rates of 1 000 000, 3 000 000, 6 000 000, 10 000 000, 30 000 000, and 100 000 000 gal. per acre daily, respectively.

This schedule of rates was carried out in a general way with all the filters, with the exception of Nos. 5 and 6. For these, the rates were found to be higher than could be maintained for any great length of time, owing to the deeper penetration of the mud in the filter sand, which caused high initial losses of head, short runs, and deep scrapings. A rate of about 30 000 000 gal. was maintained in the case of Filter No. 5 from the time it was started on September 9th, 1908,





PLAN OF FILTER-HOUSE AND EQUIPMENT

FIG. 7.

until November 8th, 1909, when it was reduced to about 17 000 000 gal., which rate was maintained thereafter until the filter was shut down in February, 1910.

In the case of Filter No. 6, it was found impossible to maintain a rate of 100 000 000 gal. for more than a very few days at a time. It was started at about this rate, however, at the beginning of each run, and kept as high as possible for the remainder of the time during the first seven runs. At the end of the seventh run, on October 17th, 1908, the filter was given a very deep scraping and re-sanded.

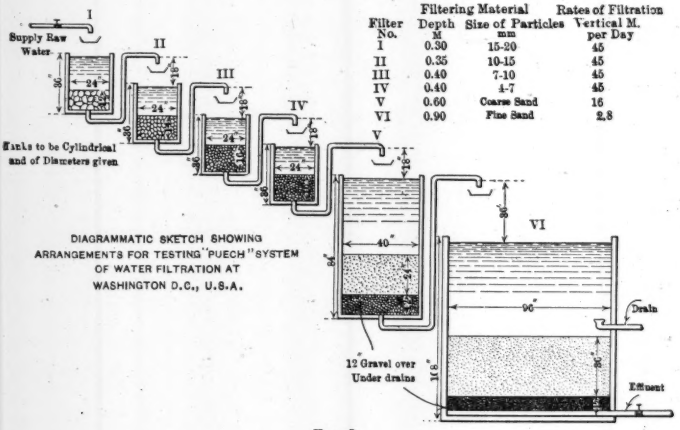


FIG. 8.

The layer of clean sand restored the original capacity, and the filter was operated as before, but with gradually decreasing rates until December, 1908, when the rate was reduced to about 40 000 000 gal. Even this lower rate was too high to be maintained without removing and replacing a large part of the sand. The rates, therefore, gradually decreased to about 23 000 000 gal. on March 13th, 1909, when the filter was again re-sanded. After this re-sanding the rate was reduced to about 20 000 000 gal., and the filter was operated at approximately that rate until it was again re-sanded on November 13th, 1909, when the rate was again reduced to about 14 000 000 gal., which was maintained until the filter was put out of service on February 28th, 1910.

This experimental plant was in service from September, 1908, to the latter part of February, 1910, or for about 1½ years, and the leading results are summarized in Table 20.

TABLE 17.—Record of Experimental Filter Plant No. 1.

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Feb. 8	19.40	0.71	3.10	0.17	...	...	..	1 100	2 000	2 500
" 9	21.50	0.81	3.11	0.16	...	...	..	200	950	500
" 10	20.60	0.95	3.04	0.14	...	...	..	.....	.....	.....
" 11	20.10	1.08	3.03	0.12	12	3	2	600	900	1 300
" 12	19.80	1.23	3.02	0.13	14	4	2	650	650	650
" 13	19.50	1.38	2.96	0.12	15	6	2	600	600	950
" 14	21.20	1.67	3.21	0.11	15	4	2	650	700	800
" 15	25.40	2.03	3.90	0.13	12	4	2	600	550	803
" 16	25.00	2.23	3.89	0.12	14	3	2	850	550	500
" 17	Shut down for changes in size of meter and piping.									
" 18	.....	....	....	....	...	...	..	1 200	.....	650
" 21	38.60	1.59	3.93	0.18	20	4	2	1 800	1 100	700
" 22	38.00	1.84	3.92	0.15	15	3	2	Holiday.		
" 23	42.10	2.36	3.95	0.14	20	5	2	1 600	600	220
" 24	47.90	3.04	3.93	0.13	20	6	3	Sunday.		
" 25	Shut down to change meter from outlet to inlet.							1 400	800	450
" 27	.....	2.24	....	0.13	17	6	3	700	550	280
" 28	49.80	2.55	3.90	0.13	15	6	3	800	470	230
Mar. 1	50.00	2.90	3.93	0.13	15	5	3	650	450	140
" 2	50.20	3.21	3.93	0.13	15	5	3	1 000	650	200
" 3	38.80	3.09	3.89	0.13	31	8	3	Sunday.		
" 4	50.00	3.54	3.93	0.12	35	10	5	1 200	.....	.....
" 5	50.00	4.01	3.90	0.13	135	39	8	13 000	3 700	600
" 6	50.00	4.82	3.90	0.13	135	39	8	18 000	4 500	.....
" 7	50.00	5.89	3.90	0.13	102	34	6	24 000	5 000	2 000
" 8	50.00	6.58	3.90	0.13	100	25	4	22 000	5 000	1 400
" 9	50.00	7.21	3.93	0.13	90	25	4	24 000	4 000	650
" 10	50.00	7.52	3.90	0.13	82	22	5	Sunday.		
	Washed.									
" 11	50.00	0.84	3.90	0.13	68	19	6	18 000	2 100	350
" 12	50.00	0.95	3.96	0.13	46	19	4	11 000	6 000	310
" 13	50.00	1.17	3.99	0.13	40	19	4	9 000	4 900	300
" 14	50.00	1.53	4.01	0.13	39	17	4	5 500	1 300	130
" 15	50.00	2.27	4.05	0.13	35	15	4	6 500	1 500	60
" 16	50.00	3.08	4.03	0.13	60	20	4	5 000	1 200	100
" 17	50.00	4.26	4.03	0.13	135	35	4	Sunday.		
" 18	50.00	5.65	4.00	0.13	170	49	7	9 000	1 200	95
" 19	50.00	7.02	4.01	0.13	125	37	6	7 000	600	100
	Washed.									
" 20	50.00	1.08	3.98	0.13	102	30	5	4 800	800	75
" 21	50.00	1.23	3.98	0.12	125	32	4	8 500	1 000	85
" 22	50.00	1.46	4.00	0.13	190	65	4	7 500	1 100	45
" 23	50.00	1.76	3.99	0.13	180	65	6	7 500	600	55
" 24	50.00	2.11	3.99	0.12	140	52	7	Sunday.		
" 25	50.00	2.46	4.00	0.11	88	30	5	4 400	500	85
" 26	50.00	2.75	4.00	0.12	62	22	4	3 600	300	65
" 27	50.00	3.04	4.08	0.13	47	18	4	2 200	160	60
" 28	50.00	3.38	3.94	0.11	35	10	3	1 300	100	55
" 29	50.00	3.70	4.00	0.11	26	8	3	700	80	29
" 30	50.00	4.42	4.00	0.11	25	6	3	310	70	35
" 31	50.00	5.25	3.99	0.11	21	5	2	Sunday.		
Apr. 1	50.00	6.14	4.00	0.12	20	5	2	600	25	30
	Washed.									
" 2	50.00	2.10	4.00	0.12	24	5	2	270	28	32
" 3	50.00	3.00	4.00	0.12	24	5	2	460	26	43

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Apr. 4.....	50.00	4.01	4.00	0.12	20	5	2	280	20	26
" 5.....	50.00	5.15	4.00	0.12	20	4	2	450	37	41
	Washed.									
" 6.....	50.00	0.76	3.59	0.12	20	4	2	320	6	34
" 7.....	50.00	0.99	3.47	0.12	20	4	2		Sunday.	
" 8.....	50.00	1.39	4.03	0.14	18	3	2	330	10	20
" 9.....	50.00	2.04	4.01	0.13	18	3	2	140	9	35
" 10.....	50.00	3.03	4.02	0.13	30	2	1	750	43	29
" 11.....	50.00	4.45	4.02	0.14	66	4	1	4 000	900	26
" 12.....	50.00	6.14	4.01	0.13	72	11	2	14 000	1 700	41
	Washed.									
" 13.....	50.00	0.95	4.00	0.14	80	21	2	13 000	1 300	70
" 14.....	50.00	1.18	4.00	0.13	77	25	3		Sunday.	
" 15.....	50.00	1.57	4.00	0.14	62	21	3	7 000	380	55
" 16.....	50.00	2.33	4.00	0.15	47	20	3	3 600	160	33
" 17.....	50.00	3.33	4.00	0.15	39	15	2	1 600	70	39
" 18.....	50.00	4.81	4.00	0.16	30	10	2	1 810	130	34
" 19.....	50.00	6.29	3.99	0.16	25	7	2	790	50	32
	Washed.									
" 20.....	50.00	0.93	4.01	0.16	20	5	2	540	24	28
" 21.....	50.00	1.36	3.97	0.16	20	3	2		Sunday.	
" 22.....	50.00	2.22	4.02	0.16	18	2	1	235	15	28
" 23.....	50.00	3.33	3.99	0.14	15	2	1	170	14	16
" 24.....	50.00	4.78	3.97	0.15	19	1	1	150	32	14
" 25.....	50.00	6.43	3.90	0.15	34	1	1	700	20	18
	Washed.									
" 26.....	50.00	0.97	3.97	0.14	46	2	1	1 200	16	16
" 27.....	50.00	2.37	4.00	0.14	52	3	1	1 700	25	17
" 28.....	50.00	5.33	3.99	0.14	45	4	1		Sunday.	
	Washed.									
" 29.....	50.00	0.81	3.99	0.14	44	5	1	600	16	17
" 30.....	50.00	1.75	3.99	0.14	39	6	1	550	27	12
May 1.....	50.00	0.80	3.99	0.14	31	5	1	500	24	11
	Washed.									
" 2.....	50.00	1.13	4.00	0.14	24	4	1	500	12	16
" 3.....	50.00	2.09	4.00	0.14	19	3	1	280	30	25
" 4.....	50.00	3.80	4.00	0.14	16	2	1	400	20	12
" 5.....	50.00	5.38	4.00	0.14	15	1	1		Sunday.	
	Washed.									
" 6.....	50.00	0.91	3.90	0.14	13	1	1	390	50	40
" 7.....	50.00	1.56	3.90	0.14	12	1	1	190	19	30
" 8.....	50.00	2.25	3.99	0.14	10	1	1	.....	.....	.....
" 9.....	50.00	3.37	4.00	0.14	10	1	1	390	21	38
" 10.....	50.00	5.16	4.00	0.14	10	1	1	300	14	13
	Washed.									
" 11.....	50.00	1.03	4.00	0.14	12	1	1	390	13	12
" 12.....	50.00	1.89	4.00	0.14	17	1	1		Sunday.	
" 13.....	50.00	3.82	4.00	0.14	35	2	1	600	33	15
" 14.....	50.00	6.31	4.00	0.14	39	3	1	500	27	7
	Washed.									
" 15.....	50.00	0.85	4.00	0.14	17	2	1	560	20	29
" 16.....	50.00	1.42	3.99	0.14	24	2	1	290	19	40
" 17.....	50.00	2.47	3.99	0.14	18	2	1	260	19	16
" 18.....	50.00	4.31	4.00	0.13	15	1	1	190	16	20
	Washed.									
" 19.....	50.00	0.83	3.99	0.13	12	1	1		Sunday.	

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
May 20.....	50.00	1.66	4.00	0.13	12	1	1	260	17	41
" 21.....	50.00	3.83	4.00	0.13	16	1	1	260	26	25
	Washed.									
" 22.....	50.00	0.82	3.99	0.13	20	1	1	280	16	19
" 23.....	50.00	1.64	4.00	0.13	15	1	1	130	20	22
" 24.....	50.00	3.85	4.00	0.13	15	1	1	170	17	32
	Washed.									
" 25.....	50.00	0.84	4.00	0.13	15	1	1	340	25	55
" 26.....	50.00	1.67	3.99	0.13	18	1	1		Sunday.	
" 27.....	50.00	3.03	4.00	0.13	13	1	1	210	10	40
	Washed.									
" 28.....	50.00	0.87	4.01	0.13	16	1	1	260	26	55
" 29.....	50.00	1.43	4.01	0.13	16	1	1	500	19	50
" 30.....	50.00	2.55	4.00	0.13	14	1	1		Holiday.	
" 31.....	50.00	4.19	4.00	0.13	17	1	1	380	22	50
June 1.....	50.00	6.26	3.99	0.13	15	1	1	900	27	50
	Washed.									
" 2.....	50.00	0.78	3.98	0.13	17	1	1		Sunday.	
" 3.....	50.00	1.19	4.00	0.13	24	1	1	550	41	50
" 4.....	50.00	2.15	4.00	0.13	37	2	1	6 500	150	60
" 5.....	50.00	3.67	4.01	0.13	65	4	1	3 200	150	46
" 6.....	50.00	6.06	4.00	0.14	77	12	1	1 500	60	27
	Washed.									
" 7.....	50.00	0.86	4.00	0.14	64	19	1	2 100	68	45
" 8.....	50.00	1.41	4.00	0.14	46	16	1	600	35	44
" 9.....	50.00	2.62	4.01	0.14	44	12	1		Sunday.	
" 10.....	50.00	4.79	4.00	0.14	36	8	1	240	31	35
	Washed.									
" 11.....	50.00	0.77	4.00	0.14	30	6	1	280	47	47
" 12.....	50.00	1.20	4.01	0.14	34	6	1	330	70	55
" 13.....	50.00	2.42	4.00	0.14	35	8	1	480	43	75
" 14.....	50.00	4.44	4.00	0.15	31	7	1	440	55	45
	Washed.									
" 15.....	50.00	0.80	3.99	0.15	32	6	1	420	17	34
" 16.....	50.00	1.15	4.00	0.15	26	5	1		Sunday.	
" 17.....	50.00	2.15	3.99	0.14	26	5	1	340	55	37
" 18.....	50.00	4.36	4.00	0.14	31	6	1	440	14	140
	Washed.									
" 19.....	50.00	0.79	4.01	0.15	37	8	1	500	70	24
" 20.....	50.00	1.19	4.00	0.15	30	7	1	330	49	27
" 21.....	50.00	2.65	3.98	0.14	25	5	1	170	30	18
" 22.....	50.00	5.58	4.00	0.14	20	4	1	100	18	13
	Washed.									
" 23.....	50.00	0.85	3.62	0.13	26	3	1		Sunday.	
" 24.....	50.00	2.02	3.99	0.13	140	11	1	1 700	27	36
" 25.....	50.00	4.77	3.99	0.13	130	26	1	400	70	23
	Washed.									
" 26.....	50.00	0.73	4.01	0.13	82	27	1	750	200	41
" 27.....	50.00	1.17	4.01	0.13	65	18	1	.....	.....	.....
" 28.....	50.00	3.10	3.99	0.13	47	16	1	.....	20	.....
	Washed.									
" 29.....	50.00	0.67	3.99	0.13	37	7	1	220	35	29
" 30.....	50.00	1.02	4.00	0.13	30	6	1		Sunday.	
July 1.....	50.00	2.70	3.99	0.13	30	6	1	400	46	3
	Washed.									

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
July 2.....	50.00	0.69	4.00	0.13	32	7	1	180	80	38
" 3.....	50.00	1.21	3.99	0.13	36	8	1	350	70	90
" 4.....	50.00	3.40	3.99	0.13	44	10	1	Holiday.		
	Washed.									
" 5.....	50.00	0.77	3.99	0.13	44	11	1	550	180	34
" 6.....	50.00	1.19	4.01	0.13	39	10	1	250	60	26
" 7.....	50.00	3.72	3.99	0.13	34	8	1	Sunday.		
	Washed.									
" 8.....	50.00	0.78	3.97	0.13	25	5	1	220	31	21
" 9.....	50.00	1.27	3.98	0.13	22	4	1	50	10	9
" 10.....	50.00	3.11	4.00	0.13	47	9	1	Lost.		
	Washed.									
" 11.....	50.00	0.83	3.99	0.13	90	19	1	150	19	8
" 12.....	50.00	1.47	3.99	0.13	97	25	1	300	40	23
" 13.....	50.00	3.61	4.00	0.13	90	29	1	220	47	16
	Washed.									
" 14.....	50.00	0.84	3.99	0.13	90	30	1	Sunday.		
" 15.....	50.00	1.30	4.00	0.13	95	30	1	375	55	21
" 16.....	50.00	2.72	3.99	0.14	120	35	1	Lost.	90	13
" 17.....	50.00	5.08	3.99	0.14	85	32	1	270	27	11
	Washed.									
" 18.....	50.00	0.85	3.99	0.14	56	22	1	1 675	70	50
" 19.....	50.00	1.43	4.00	0.14	41	12	1	450	95	22
" 20.....	50.00	3.23	3.99	0.14	62	19	1	300	38	11
	Washed.									
" 21.....	50.00	0.80	3.99	0.14	62	21	1	Sunday.		
" 22.....	50.00	1.06	3.98	0.14	80	26	1	1 400	150	7
" 23.....	50.00	2.18	3.99	0.14	105	30	1	3 700	Lost.	11
" 24.....	50.00	4.95	3.98	0.15	95	30	1	770	"	22
	Washed.									
" 25.....	50.00	0.84	3.98	0.15	77	22	1	250	33	11
" 26.....	50.00	1.22	3.98	0.15	67	19	1	140	100	4
" 27.....	50.00	2.36	4.00	0.16	54	15	1	300	95	7
" 28.....	50.00	4.74	3.98	0.16	46	12	1	Sunday.		
	Washed.									
" 29.....	50.00	0.83	3.99	0.17	36	10	1	470	110	18
" 30.....	50.00	1.02	4.00	0.17	29	7	1	Plates lost.		
" 31.....	50.00	1.66	4.00	0.17	21	5	1	"	"	
Aug. 1.....	48.20	2.95	4.00	0.17	16	4	1	"	"	
" 2.....	46.40	4.96	4.00	0.17	15	2	1	180	42	13
	Washed.									
" 3.....	42.60	0.79	4.00	0.17	16	1	1	120	4	16
" 4.....	49.10	0.91	4.00	0.17	21	1	1	Sunday.		
" 5.....	49.10	1.59	4.00	0.17	29	1	1	230	160	11
" 6.....	48.20	3.16	4.00	0.17	34	2	1	85	200	12
" 7.....	45.60	5.65	3.99	0.17	21	2	1	200	Lost.	4
	Washed.									
" 8.....	50.00	0.80	3.99	0.17	19	2	1	100	70	11
" 9.....	49.10	0.94	4.00	0.17	16	1	1	75	44	9
" 10.....	48.20	1.51	4.00	0.17	24	1	1	60	13	6
" 11.....	48.20	3.32	4.00	0.17	62	3	1	Sunday.		
	Washed.									
" 12.....	41.90	0.83	3.99	0.17	120	14	1	620	110	5
" 13.....	49.10	1.14	3.99	0.17	107	29	1	820	53	36
" 14.....	49.10	1.72	4.00	0.18	82	30	1	850	160	110
" 15.....	48.20	3.30	4.00	0.18	65	22	1	150	37	4
	Washed.									

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Aug. 16.....	46.40	0.84	4.00	0.19	45	15	1	270	110	13
" 17.....	48.20	1.05	4.00	0.19	35	10	1	340	110	6
" 18.....	50.00	1.54	4.00	0.19	21	5	1		Sunday.	
" 19.....	49.10	2.29	4.00	0.19	18	4	1	180	85	13
" 20.....	49.10	3.74	3.99	0.19	20	2	1	210	85	8
	Washed.									
" 21.....	44.10	1.01	3.98	0.19	20	2	1	1 300	115	9
" 22.....	45.60	1.86	4.00	0.19	27	2	1	3 800	265	1
" 23.....	47.30	4.08	3.99	0.19	49	2	1	2 500	70	13
	Washed.									
" 24.....	41.30	1.29	3.97	0.19	36	6	1	3 900	46	6
" 25.....	44.10	2.11	3.98	0.20	34	7	1		Sunday.	
" 26.....	48.20	3.42	3.99	0.20	21	5	1	700	140	0
" 27.....	48.20	5.10	4.00	0.20	19	4	1	470	100	4
	Washed.									
" 28.....	46.40	1.28	4.00	0.20	18	3	1	500	49	3
" 29.....	41.90	1.90	4.02	0.20	17	2	1	360	80	0
" 30.....	45.60	3.23	4.00	0.20	15	1	1	320	190	1
" 31.....	46.40	4.57	4.00	0.20	13	1	1	200	20	3
Sept. 1.....	50.00	5.17	3.65	0.20	14	1	1		Sunday.	
" 2.....	48.20	5.97	4.00	0.20	12	1	1		Holiday.	
	Washed.									
" 3.....	47.30	1.13	4.00	0.20	12	1	1	300	9	1
" 4.....	48.20	2.01	4.00	0.20	16	1	1	600	60	2
" 5.....	46.40	5.41	3.67	0.20	34	1	0	360	72	....
	Washed.									
" 6.....	40.60	1.42	3.98	0.20	160	12	0	15 000	140	0
" 7.....	42.60	5.19	3.99	0.20	64	18	1	2 000	180	1
	Washed.									
" 8.....	42.60	1.25	4.00	0.20	56	18	1		Sunday.	
" 9.....	46.40	3.07	4.00	0.22	59	18	1	220	80	4
	Washed.									
" 10.....	45.60	1.02	3.99	0.23	57	16	1	18 000	57	8
" 11.....	48.20	2.36	4.00	0.23	65	18	1	2 700	90	1
	Washed.									
" 12.....	44.10	1.14	3.99	0.24	72	18	1	1 000	47	4
" 13.....	46.40	3.61	3.99	0.25	87	20	1	2 300	77	5
	Washed.									
" 14.....	38.20	1.42	3.97	0.26	72	19	1	2 400	80	5
" 15.....	45.60	4.27	4.00	0.27	65	18	1		Sunday.	
	Washed.									
" 16.....	40.00	1.06	3.99	0.28	65	18	1	Lost.	22	Lost.
" 17.....	46.40	2.48	4.01	0.28	52	16	1	420	75	1
	Washed.									
" 18.....	46.40	1.11	4.00	0.28	60	13	1	900	37	3
" 19.....	46.40	2.76	4.00	0.28	85	16	1	2 000	186	0
	Washed.									
" 20.....	44.10	1.12	4.00	0.31	100	19	1	4 200	110	7
" 21.....	48.20	2.07	3.99	0.33	120	24	1	1 100	110	3
	Washed.									
" 22.....	44.10	1.30	3.67	0.34	137	29	1		Sunday.	
" 23.....	45.60	3.79	3.99	0.39	112	25	1	2 400	50	2
	Washed.									
" 24.....	45.60	1.15	3.97	0.40	100	25	1	4 000	69	4
" 25.....	48.20	2.06	4.00	0.42	432	53	1	56 000	680	6
" 26.....	Stopped, unable to wash preliminary.									

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Sept. 28.....	50.00	1.74	4.00	0.71	127	35	1	.....	.....	37
	Washed.									
" 29.....	44.10	2.85	3.99	0.82	105	31	1		Sunday.	
" 30.....	44.90	3.78	3.97	1.04	115	32	1	Lost.	Lost.	160
	Washed.									
Oct. 1.....	44.10	1.20	3.98	1.34	82	26	1	600	180	55
" 2.....	49.10	3.22	3.97	1.54	65	19	1	4 400	120	5
	Washed.									
" 3.....	44.10	1.31	3.97	1.56	59	17	1	900	55	10
" 4.....	49.10	2.97	3.97	1.65	55	15	1	850	60	6
	Washed.									
" 5.....	44.90	1.31	3.98	1.75	59	16	1	2 000	110	38
" 6.....	46.40	3.65	3.99	1.89	59	17	1		Sunday.	
	Washed.									
" 7.....	44.90	1.34	3.98	1.99	52	13	1	1 250	70	15
" 8.....	49.10	3.49	3.98	2.17	54	13	1	11 000	65	6
	Washed.									
" 9. ...	44.10	1.20	3.97	2.33	51	13	1	2 000	85	4
" 10.....	49.10	2.22	3.98	2.53	50	12	1	800	36	10
" 11.....	46.40	4.59	4.00	2.51	47	11	1	2 000	57	10
" 12.....	Shut off to remove sand in preliminary filter in order to clean out the under-drains.									
Nov. 5.....	50.00	1.38	3.97	3.49	125	50	1	.....	.....	.....
" 6.....	48.20	3.25	3.98	3.79	170	52	1	5 000	1 500	240
	Washed.									
" 7.....	45.60	1.18	3.98	4.05	100	35	1	14 000	1 000	220
" 8.....	48.20	4.08	3.99	4.37	95	32	1	1 900	270	160
" 9.....	42.00	6.58	3.98	4.39	80	27	1	4 000	500	190
" 10.....	Shut down for scraping. Removed 266 000 cu. cm. of sand.									
" 12.....	50.00	0.98	3.99	0.25	40	10	1	.....	.....	.....
" 13.....	50.00	1.51	4.00	0.22	36	8	1	1 600	750	85
" 14.....	48.20	2.60	4.00	0.21	42	11	1	2 700	700	210
" 15.....	47.30	3.80	4.00	0.20	35	9	1	1 800	350	180
" 16.....	47.30	4.87	4.00	0.19	26	5	1	1 100	200	34
" 17.....	50.00	5.75	4.00	0.19	20	4	1		Sunday.	
" 18.....	50.00	6.41	4.00	0.19	17	3	1	1 600	290	55
	Washed.									
" 19.....	48.20	1.06	3.99	0.20	16	2	1	1 300	480	60
" 20.....	48.20	2.05	3.99	0.20	45	3	1	6 500	3 700	800
" 21.....	48.20	3.48	3.99	0.20	52	9	1	9 900	4 000	300
" 22.....	47.30	4.85	3.99	0.20	65	17	1	10 000	1 000	380
" 23.....	48.20	6.11	3.99	0.20	49	15	1	18 000	1 000	320
	Washed.									
" 24.....	46.40	3.74	3.98	0.20	134	24	1		Sunday.	
" 25.....	Shut down for fear of washing preliminary with such muddy water.									
" 29.....	50.00	1.55	4.00	0.21	80	25	1	.....	.....	.....
" 30.....	47.30	3.14	3.98	0.22	54	16	1	3 800	950	160
Dec. 1.....	47.30	4.48	3.98	0.23	37	10	1		Sunday.	
" 2.....	47.30	5.63	3.98	0.25	30	6	1	2 900	550	90
	Washed.									
" 3.....	46.40	0.98	3.99	0.25	29	6	1	2 900	480	75
" 4.....	50.00	1.15	3.99	0.26	20	4	1	2 000	270	70
" 5.....	50.00	1.48	4.00	0.25	18	3	1	1 100	270	50
" 6.....	48.20	2.04	3.63	0.25	16	2	1	3 000	.....	.....

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Dec. 7	48.20	2.80	4.00	0.26	14	1	1	2 400	190	10
" 8	50.00	3.40	3.72	0.27	12	1	1		Sunday.	
" 9	49.10	3.93	4.00	0.27	11	1	1	1 200	170	7
" 10	49.10	4.50	4.00	0.27	12	1	1	800	90	55
" 11	48.20	5.52	4.00	0.27	255	44	1	6 500	.....	.....
" 12	Shut down 12/11 at 6 P. M., turbidity too high to wash.									
" 15	.....	....	....	....	.....	.....	....		Sunday.	
" 16	50.00	4.02	3.99	0.28	90	35	2	.....	.....	.....
	Washed.									
" 17	40.00	1.90	3.97	0.30	70	25	2	21 000	10 000	1 200
	Washed.									
" 18	44.10	1.08	3.97	0.31	49	15	2	6 500	4 200	800
" 19	48.20	1.88	3.98	0.31	39	10	1	Lost.	Lost.	Lost.
" 20	46.40	4.77	3.99	0.31	42	13	1	"	"	"
" 21	46.40	6.68	3.99	0.32	26	6	1	"	"	"
	Washed.									
" 22	49.10	1.14	3.99	0.32	20	4	1		Sunday.	
" 23	49.10	2.17	4.00	0.31	34	7	1	1 400	300	100
" 24	49.10	3.76	4.00	0.31	195	56	1	9 000	950	70
" 25	Shut down 12/24 at 9 P. M., turbidity too high to wash.								Holiday.	
" 30	50.00	2.61	3.97	0.33	56	19	2	.....	.....	.....
" 31	44.80	5.57	3.98	0.36	39	12	1	.....	.....	.....
	Washed.									
1908.										
Jan. 1	46.40	1.30	3.98	0.36	31	6	1		Holiday.	
" 2	48.20	3.36	4.00	0.36	39	9	1	.....	.....	.....
" 3	47.30	4.95	3.99	0.35	36	9	1	3 100	490	90
" 4	50.00	5.28	3.99	0.35	32	7	1	2 400	240	43
" 5	49.10	6.26	4.00	0.35	26	5	1		Sunday.	
	Washed.									
" 6	49.10	0.99	3.98	0.35	20	4	1	600	200	37
" 7	50.00	1.15	4.00	0.35	20	4	1	1 100	150	47
" 8	50.00	1.41	4.00	0.35	22	4	1	1 900	160	30
" 9	49.10	1.92	4.00	0.35	45	11	1	13 000	1 300	70
" 10	49.10	2.56	4.00	0.36	70	25	1	10 000	3 500	170
" 11	50.00	3.17	3.99	0.37	56	18	1	16 000	4 000	240
" 12	49.10	3.73	4.00	0.37	40	10	1		Sunday.	
" 13	50.00	4.14	4.00	0.37	110	45	2	8 500	1 200	340
" 14	49.10	4.65	3.39	0.38	210	95	3	16 000	3 900	500
" 15	49.10	5.23	3.99	0.41	325	190	12	24 000	7 000	550
" 16	50.00	5.75	3.99	0.43	360	210	37	28 000	8 500	1 200
" 17	49.10	6.34	4.00	0.45	242	122	24	65 000	15 000	1 700
" 18	.....	....	....	....	....	....	....	.....	.....	.....
" 19	50.00	1.17	4.30	0.46	117	40	12		Sunday.	
" 20	50.00	1.38	4.00	0.46	72	31	6	1 600	1 800	320
" 21	50.00	1.68	3.57	0.37	55	20	4	5 000	450	.....
" 22	49.10	2.04	4.00	0.44	49	17	3	3 600	600	100
" 23	50.00	2.47	3.24	0.33	40	12	3	1 800	290	130
" 24	49.10	3.03	3.00	0.34	40	11	2	2 300	270	65
" 25	50.00	3.61	3.00	0.35	39	10	2	1 100	180	60
" 26	49.10	4.18	2.99	0.35	32	7	2		Sunday.	
" 27	50.00	4.81	3.00	0.35	32	7	2	300	40	24
" 28	48.20	5.45	2.99	0.35	45	12	2	1 200	90	31
" 29	49.10	6.01	2.99	0.35	60	21	2	1 000	230	50
" 30	49.10	6.62	2.99	0.36	57	22	2	1 400	170	43
	Washed.									
" 31	50.00	1.80	2.99	0.36	42	15	2	1 100	190	23

TABLE 17.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1908.										
Feb. 1.	50.00	1.51	2.99	0.37	39	11	2	750	40	31
" 2.	50.00	1.78	3.00	0.37	27	7	2		Sunday.	
" 3.	49.10	2.13	3.00	0.37	29	6	2	1 300	200	7
" 4.	50.00	2.69	3.00	0.37	25	5	1	600	160	18
" 5.	49.10	3.31	2.99	0.37	24	5	1	750	140	41
" 6.	50.00	3.89	2.99	0.37	20	4	1	2 000	180	29
" 7.	48.20	4.50	2.99	0.37	17	3	1	.....	38	15
" 8.	49.10	5.11	2.99	0.37	15	3	1	900	95	24
" 9.	49.10	5.65	3.00	0.38	14	3	1		Sunday.	
" 10.	49.10	6.43	2.99	0.38	11	3	1	850	85	21
" 11.	50.00	6.90	3.00	0.38	10	3	1	1 000	70	20
	Washed.									
" 12.	49.10	1.29	2.99	0.38	8	2	1	750	20	16
" 13.	50.00	1.50	2.99	0.39	9	2	1	700	40	11
" 14.	50.00	1.80	2.99	0.39	9	2	1	1 200	39	7
" 15.	49.10	2.35	3.00	0.39	61	13	1	5 500	600	7
" 16.	49.10	3.28	2.99	0.39	80	30	2		Sunday.	
" 17.	48.20	4.85	2.99	0.39	80	29	3	33 000	3 800	130
" 18.	47.30	6.39	2.99	0.39	130	44	3	.....	2 600	160
" 19.	45.50	7.32	2.98	0.40	320	143	6	28 000	6 000	180
	Washed.									
" 22.	50.00	1.40	3.00	0.41	85	30	5		Holiday.	
" 23.	50.00	1.77	3.00	0.41	60	21	4		Sunday.	
" 24.	49.10	2.25	2.99	0.41	46	14	3	3 600	2 800	90
" 25.	50.00	2.61	3.00	0.41	31	7	2	2 300	140	47
" 26.	50.00	3.06	3.00	0.41	30	6	2	3 800	140	45
" 27.	48.20	3.65	2.99	0.41	30	5	1	1 300	100	22
" 28.	50.00	4.24	3.00	0.41	37	6	1	1 400	100	40
" 29.	48.20	5.28	2.99	0.41	123	52	2	13 500	420	40
	Washed.									
Mar. 1.	44.60	1.56	2.99	0.42	97	39	5		Sunday.	
" 2.	48.20	2.90	2.99	0.42	82	30	4	8 000	320	60
" 3.	46.40	4.69	2.98	0.42	87	33	4	11 000	750	30
" 4.	47.30	6.13	2.99	0.42	67	24	3	6 000	290	34
" 5.	48.20	7.31	2.99	0.42	59	19	3	4 400	220	41
	Washed.									
" 6.	49.10	1.53	2.99	0.42	72	24	2	7 000	170	41
" 7.	50.00	1.95	3.00	0.43	82	30	2	9 500	210	34
" 8.	49.10	2.62	2.99	0.43	92	37	3		Sunday.	
" 9.	50.00	3.19	3.00	0.43	125	56	4	11 000	700	65
" 10.	Preliminary filter discontinued and the Puech system started.									

TABLE 17.—RECORD OF EXPERIMENTAL FILTER, PUECH SYSTEM.—(*Continued.*)

Date.	PUECH SYSTEM: Rates, millions of gallons per acre daily.					FINAL FILTER.		TURBIDITY.			BACTERIA.		
						Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1908.													
Mar. 11...	265	170	90	53	18	2.99	0.53	155	80	7	6 500	8 500	490
" 12...	265	170	90	53	18	2.99	0.60	135	70	7	5 900	6 000	360
" 13...	265	170	90	53	18	3.00	0.60	122	52	6	1 900	1 700	140
" 14...	265	170	90	53	18	3.00	0.61	97	40	5	1 800	1 600	130
" 15...	265	170	90	53	18	2.99	0.64	77	31	4		Sunday.	
" 16...	265	170	90	53	18	3.00	0.69	65	26	3	1 400	1 200	50
" 17...	241	155	82	48	16	2.99	0.71	59	19	3	900	200	45
" 18...	252	162	86	50	17	2.99	0.75	67	22	2	1 000	700	33
" 19...	241	155	82	48	16	2.99	0.78	60	21	2	.....	800	44
" 20...	294	189	100	59	20	2.99	0.85	57	18	2	1 300	650	37
" 21...	279	179	95	56	19	2.99	0.92	67	21	2	800	600	34
" 22...	265	170	90	53	18	2.99	0.99	80	27	2		Sunday.	
" 23...	265	170	90	53	18	2.99	1.06	90	32	2	4 600	1 300	33
" 24...	265	170	90	53	18	2.99	1.12	82	34	3	2 500	950	38
" 25...	265	170	90	53	18	2.99	1.18	67	27	3	1 600	....	30
" 26...	265	170	90	53	18	2.99	1.22	60	20	3	550	400	24
" 27...	265	170	90	53	18	3.00	1.23	59	18	2	950	360	28
" 28...	265	170	90	53	18	3.00	1.25	51	14	2	650	230	18
" 29...	265	170	90	53	18	2.99	1.28	31	6	2		Sunday.	
" 30...	265	170	90	53	18	2.99	1.36	30	5	1	500	160	25
" 31...	265	170	90	53	18	2.99	1.43	39	7	1	750	140	26
April 1...	265	170	90	53	18	3.00	1.48	44	9	1	750	60	41
" 2...	265	170	90	53	18	2.99	1.56	42	9	1	1 100	140	26
" 3...	318	204	108	64	22	2.99	1.63	41	8	1	1 500	47	11
" 4...	294	189	100	59	20	2.99	1.70	54	13	1	700	80	35
" 5...	279	179	95	56	19	3.00	1.73	50	13	1		Sunday.	
" 6...	279	179	95	56	19	2.99	1.76	41	9	1	440	65	17
" 7...	265	170	90	53	18	3.00	1.78	35	6	1	650	65	34
" 8...	265	170	90	53	18	3.00	1.79	39	6	1	550	44	10
" 9...	265	170	90	53	18	3.00	1.79	40	6	1	390	30	25
" 10...	265	170	90	53	18	3.00	1.77	40	6	1	500	27	16
" 11...	265	170	90	53	18	3.00	1.78	45	7	1	430	28	28
" 12...	265	170	90	53	18	2.99	1.80	52	11	1		Sunday.	
" 13...	265	170	90	53	18	....	1.81	50	10	1	490	17	26
" 14...	Shut down on account of losing water when aqueduct was drained; also cleaned coarse sand filter. Started April 22d.												
" 23...	241	155	82	48	16	....	1.82	29	4	1	140	600	38
" 24...	241	155	82	48	16	3.00	1.87	21	3	1	200	1 000	13
" 25...	241	155	82	48	16	2.99	1.95	20	3	1	85	180	25
" 26...	252	162	86	50	17	3.00	1.95	24	3	1		Sunday.	
" 27...	241	155	82	48	16	3.00	1.93	18	2	1	95	35	23
" 28...	241	155	82	48	16	3.00	1.96	20	2	1	70	24	18
" 29...	241	155	82	48	16	2.99	1.97	24	3	1	110	21	24
" 30...	241	155	82	48	16	2.99	2.03	21	2	1	70	25	6
May 1...	241	155	82	48	16	3.00	2.07	32	4	1	130	20	18
" 2...	241	155	82	48	16	2.99	2.12	26	3	1	140	16	12
" 3...	241	155	82	48	16	2.99	2.17	22	3	1		Sunday.	
" 4...	241	155	82	48	16	3.00	2.19	19	2	1	85	30	17
" 5...	241	155	82	48	16	3.00	2.20	18	2	1	130	33	9
" 6...	241	155	82	48	16	2.99	2.23	18	2	1	230	55	6
" 7...	252	162	86	50	17	3.00	2.24	19	2	1	160	75	10
" 8...	241	155	82	48	16	3.00	2.25	19	2	1	375	55	8
" 9...	318	204	108	64	22	2.99	2.29	18	2	1	1 200	12	9
" 10...	318	204	108	64	22	2.99	2.30	30	3	1		Sunday.	
" 11...	265	170	90	53	18	2.99	2.33	60	10	1	2 800	130	11
" 12...	252	162	86	50	17	2.99	2.39	70	15	1	2 900	135	9

TABLE 17.—(*Continued.*)

Date.	Puech system: Rates, millions of gallons per acre daily.					Final filter. Rate, millions of gallons per acre daily.	Final filter. Loss of head.	Turbidity. Applied water.	Turbidity. Effluent, preliminary filter.	Turbidity. Effluent, final filter.	Bacteria. Applied water.	Bacteria. Effluent, preliminary filter.	Bacteria. Effluent, final filter.
1908.													
May 13...	241	155	82	48	16	3.00	2.41	66	14	1	1 800	110	16
" 14...	265	170	90	53	18	3.00	2.38	45	7	1	2 700	65	18
" 15...	252	162	86	50	17	3.00	2.41	39	5	1	950	45	14
" 16...	241	155	82	48	16	3.00	2.41	49	7	1	800	32	10
" 17...	241	155	82	48	16	3.01	2.34	46	7	1	Sunday.		
" 18...	241	155	82	48	16	3.00	2.31	31	4	1	700	26	6
" 19...	252	162	86	50	17	3.00	2.26	36	4	1	375	28	17
" 20...	252	162	86	50	17	3.00	2.20	41	5	1	425	38	11
" 21...	344	221	117	69	23	3.00	2.18	30	3	1	300	25	9
" 22...	241	155	82	48	16	3.01	2.17	53	7	1	950	220	18
" 23...	265	170	90	53	18	2.99	2.25	127	38	1	2 400	600	21
" 24...	331	212	112	66	22	3.00	2.19	110	39	3	Sunday.		
" 25...	318	204	108	64	22	3.01	2.02	90	25	3	600	300	40
" 26...	279	179	95	56	19	3.02	1.87	135	45	3	3 200	110	34
" 27...	265	170	90	53	18	3.01	1.63	110	39	3	1 450	320	45
" 28...	252	162	86	50	17	3.01	1.41	90	27	3	1 000	95	28
" 29...	252	162	86	50	17	3.01	1.24	70	17	3	1 100	150	26
" 30...	252	162	86	50	17	3.01	1.07	50	9	2	Holiday.		
" 31...	241	155	82	48	16	3.01	1.03	34	4	2	Sunday.		
June 1...	252	162	86	50	17	3.00	0.83	35	4	1	....	....	..
" 2...	241	155	82	48	16	3.00	0.74	39	5	1	....	....	..
" 3...	252	162	86	50	17	3.00	0.68	35	4	1	....	....	..
" 4...	241	155	82	48	16	3.00	0.63	30	3	1	....	....	..
" 5...	252	162	86	50	17	2.99	0.60	30	3	1	....	....	..
" 6...	241	155	82	48	16	3.00	0.56	27	3	1	....	....	..
" 7...	241	155	82	48	16	2.99	0.53	22	2	1	....	....	..
" 8...	241	155	82	48	16	3.00	0.49	20	1	1	....	....	..
" 9...	241	155	82	48	16	2.99	0.46	20	1	1	....	....	..
" 10...	241	155	82	48	16	3.00	0.44	17	1	1	....	....	..
" 11...	331	212	112	66	22	2.98	0.42	12	1	1	....	....	..
" 12...	318	204	108	64	22	2.98	0.42	11	1	1	....	....	..
" 13...	265	170	90	53	18	3.00	0.40	36	3	1	....	....	..
" 14...	252	162	86	50	17	2.99	0.40	39	5	1	....	....	..
" 15...	241	155	82	48	16	2.99	0.39	25	3	1	....	....	..
" 16...	241	155	82	48	16	2.99	0.40	34	3	1	....	....	..
" 17...	252	162	86	50	17	2.99	0.41	64	11	1	....	....	..
" 18...	241	155	82	48	16	2.99	0.42	57	11	1	....	....	..
" 19...	241	155	82	48	16	2.99	0.42	46	8	1	....	....	..
" 20...	241	155	82	48	16	2.99	0.42	40	5	1	....	....	..
" 21...	241	155	82	48	16	3.00	0.43	28	4	1	....	....	..
" 22...	241	155	82	48	16	2.99	0.43	25	3	1	....	....	..
" 23...	241	155	82	48	16	2.99	0.43	25	3	1	....	....	..
" 24...	241	155	82	48	16	2.99	0.43	29	4	1	....	....	..
" 25...	241	155	82	48	16	2.99	0.43	18	2	1	....	....	..
" 26...	241	155	82	48	16	2.80	0.42	15	1	1	....	....	..
" 27...	241	155	82	48	16	2.99	0.44	12	1	1	....	....	..
" 28...	241	155	82	48	16	2.99	0.44	9	1	1	....	....	..
" 29...	241	155	82	48	16	2.99	0.44	8	1	1	....	....	..
" 30...	241	155	82	48	16	2.99	0.44	10	1	1	....	....	..
July 1...	241	155	82	48	16	3.00	0.45	8	1	1	80	10	4
" 2...	241	155	82	48	16	3.00	0.46	8	1	0	290	24	5
" 3...	241	155	82	48	16	3.00	0.47	8	1	0	350	45	6
" 4...	241	155	82	48	16	2.99	0.49	9	1	0	....	....	..
" 5...	305	195	103	61	21	3.00	0.51	10	1	0	....	....	..
" 6...	241	155	82	48	16	3.00	0.51	9	1	0	300	36	7
" 7...	241	155	82	48	16	2.99	0.53	8	1	0	110	10	3

TABLE 17.—(*Continued.*)

Date.	Puech system: Rates, millions of gallons per acre daily.					Final filter. Rate, millions of gallons per acre daily.	Final filter. Loss of head.	Turbidity. Applied water.	Turbidity. Effluent, preliminary filter.	Turbidity. Effluent, final filter.	Bacteria. Applied water.	Bacteria. Effluent, preliminary filter.	Bacteria. Effluent, final filter.
1908, July 8...	252	162	86	50	17	3.00	0.53	9	1	0	85	22	2
" 9...	241	155	82	48	16	3.00	0.54	8	1	0	85	26	2
" 10...	...	...	...	..	..	.....	.....	..	..	..	200	3	5
" 11...	305	195	103	61	21	3.00	0.56	12	1	0	145	7	3
" 12...	241	155	82	48	16	2.99	0.58	11	1	0	.....	.....	..
" 13...	241	155	82	48	16	3.00	0.60	10	1	0	115	34	55
" 14...	241	155	82	48	16	2.99	0.62	16	1	0	300	55	30
" 15...	241	155	82	48	16	2.99	0.64	17	1	0	180	32	23
" 16...	241	155	82	48	16	3.00	0.67	13	1	0	100	115	3
" 17...	241	155	82	48	16	2.99	0.71	10	1	0	65	275	5
" 18...	241	155	82	48	16	2.99	0.73	11	1	0	38	425	10
" 19...	241	155	82	48	16	3.00	0.76	12	1	0	.....	.....	..
" 20...	241	155	82	48	16	2.99	0.79	10	1	0	95	90	70
" 21...	252	162	86	50	17	2.99	0.83	10	1	1	70	17	4
" 22...	241	155	82	48	16	2.99	0.87	13	1	1	450	8	5
" 23...	305	195	103	61	21	2.99	0.92	54	4	1	650	26	5
" 24...	331	212	111	66	22	2.98	0.99	305	61	1	1 650	.....	..
" 25...	265	170	90	53	18	2.98	1.08	330	85	1	2 600	115	15
" 26...	252	162	86	50	17	2.98	1.21	290	77	2	.....	.....	..
" 27...	305	195	103	61	21	2.98	1.40	335	87	2	35 000	250	..
" 28...	252	162	86	50	17	2.98	1.68	170	52	2	1 200	1 350	15
" 29...	252	162	86	50	17	2.97	2.14	180	52	2	2 000	600	13
" 30...	252	162	86	50	17	2.97	2.65	237	56	2	800	1 300	12
" 31...	241	155	82	48	16	2.95	3.01	250	60	2	1 000	310	7

TABLE 18.—Record of Experimental Filter Plant No. 2.

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Feb. 8....	21.50	0.04	2.81	0.17	....	....	....	1 100	2 100	.....
" 9....	21.60	0.04	1.09	0.06	....	....	....	200	550	2 100
" 10....	20.90	0.05	1.59	0.08	....	....	....	.....	.....	.....
" 11....	19.80	0.05	3.01	0.15	12	6	2	600	1 100	1 100
" 12....	19.70	0.06	3.01	0.14	12	5	2	650	400	700
" 13....	19.60	0.06	3.01	0.12	15	5	2	600	900	700
" 14....	24.70	0.07	2.65	0.13	15	6	2	650	1 100	900
" 15....	37.20	.. .	3.40	0.12	12	5	2	600	800	850
" 16....	37.30	....	3.40	0.11	14	4	2	850	950	600
" 17....	Shut down for changes in meters and piping.									
" 18....	.....	....	.....	....	....	....	....	1 200	.....	600
" 21....	44.50	....	4.36	0.19	20	6	2	1 800	1 400	800
" 22....	48.60	....	4.37	0.16	15	4	2		Holiday.	
" 23....	48.40	....	4.20	0.15	20	7	2	1 600	750	380
" 24....	48.30	....	4.02	0.13	20	10	3		Sunday.	
" 25....	Shut down several hours.				0.14	20	10	3	1 400	1 000	450
" 26....	48.60	0.04	4.12	0.14	20	10	3	700	800	260
" 27....	53.20	0.04	4.08	0.15	17	8	3	700	700	290
" 28....	52.80	0.04	4.09	0.15	15	8	3	800	650	500
Mar. 1....	53.00	0.04	4.10	0.16	15	8	3	650	550	200
" 2....	53.30	0.04	4.11	0.16	15	7	3	1 000	800	300
" 3....	50.60	0.05	4.11	0.16	31	11	3		Sunday.	
" 4....	42.40	0.05	4.12	0.17	35	15	6	1 200	1 500	360
" 5....	42.70	0.05	4.11	0.17	135	52	10	13 000	850	....
" 6....	48.60	0.07	4.13	0.17	135	54	12	18 000	8 000	....
" 7....	50.50	0.08	4.12	0.18	102	46	8	24 000	6 500	1 800
" 8....	51.80	0.09	4.12	0.18	100	40	6	22 000	6 000	1 600
" 9....	53.00	0.10	4.12	0.18	90	40	5	24 000	6 000	800
" 10....	54.40	0.12	4.11	0.19	82	39	6		Sunday.	
" 11....	51.00	0.12	4.12	0.19	68	32	7	18 000	4 300	240
" 12....	51.20	0.12	4.07	0.19	46	25	5	11 000	4 600	210
" 13....	50.50	0.12	4.00	0.19	40	20	5	9 000	1 500	200
" 14....	46.50	0.12	....	0.20	39	20	4	5 500	1 200	90
" 15....	45.80	0.12	3.98	0.20	35	18	4	6 500	1 100	150
" 16....	42.50	0.12	3.97	0.19	60	24	4	5 000	800	160
" 17....	49.30	0.14	3.98	0.19	135	45	5		Sunday.	
" 18....	52.60	0.16	3.98	0.20	170	59	9	9 000	1 700	100
" 19....	53.50	0.17	4.01	0.19	125	51	8	7 000	1 000	120
" 20....	52.99	0.17	3.99	0.18	102	40	6	4 800	700	75
" 21....	48.20	0.16	4.00	0.19	125	42	5	8 500	1 100	90
" 22....	51.80	0.18	4.01	0.20	190	82	5	7 500	1 100	55
" 23....	51.60	0.19	4.01	0.20	180	75	6	7 500	1 300	90
" 24....	48.20	0.17	4.01	0.20	140	68	7		Sunday.	
" 25....	48.50	0.18	4.01	0.20	88	40	5	4 400	900	75
" 26....	45.90	0.18	3.98	0.20	62	32	4	3 600	750	90
" 27....	50.50	0.20	4.04	0.20	47	25	4	2 200	400	60
" 28....	49.60	0.20	3.92	0.19	35	16	3	1 300	350	55
" 29....	42.20	0.17	3.98	0.19	26	12	3	700	180	20
" 30....	48.00	0.22	4.01	0.19	25	7	3	310	220	39
" 31....	49.10	0.22	3.99	0.20	21	6	2		Sunday.	
April 1....	49.10	0.24	4.00	0.20	20	6	2	600	110	38
" 2....	49.70	0.25	4.00	0.20	24	6	2	270	110	29
" 3....	51.40	0.27	4.00	0.21	24	6	2	460	85	31
" 4....	48.70	0.27	4.00	0.22	20	6	2	280	60	22
" 5....	48.10	0.27	4.00	0.22	20	5	2	450	70	40
" 6....	Shut down awaiting Mr. Maignen to apply bone-charcoal.									
" 7....	Removed 1.06 in. of sand.								Sunday.	

TABLE 18.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
April 8....	52.20	0.33	4.05	0.27	18	4	3	330	.....	.....
" 9....	46.90	0.29	4.02	0.29	18	4	2	140	60	32
" 10....	47.60	0.31	4.03	0.28	30	4	1	750	120	28
" 11....	46.00	0.30	4.04	0.28	66	7	2	4 000	.....	32
" 12....	45.40	0.31	4.03	0.29	72	20	3	14 000	2 900	85
" 13....	45.10	0.32	3.99	0.32	80	30	3	13 000	2 500	95
" 14....	49.00	0.34	4.00	0.32	77	35	4		Sunday.	
" 15....	47.80	0.35	3.99	0.33	62	31	4	7 000	1 100	60
" 16....	47.40	0.36	3.99	0.34	47	27	4	3 600	650	31
" 17....	45.60	0.36	4.00	0.34	39	21	3	1 600	160	38
" 18....	45.70	0.36	4.00	0.34	30	13	2	1 810	210	42
" 19....	45.60	0.37	4.00	0.34	25	9	2	790	190	34
" 20....	45.30	0.40	4.00	0.36	20	6	2	540	87	28
" 21....	47.20	0.44	3.99	0.38	20	4	2		Sunday.	
" 22....	45.20	0.42	3.99	0.38	18	3	1	235	55	22
" 23....	44.90	0.44	4.05	0.40	15	3	1	170	45	16
" 24....	40.50	0.41	4.02	0.44	19	2	1	150	14	14
" 25....	39.60	0.41	4.03	0.45	34	3	1	700	12	23
" 26....	40.70	0.44	4.05	0.45	46	4	1	1 200	80	16
" 27....	39.80	0.44	4.00	0.44	52	4	1	1 700	160	23
" 28....	34.70	0.43	4.05	0.44	45	5	1		Sunday.	
" 29....	37.20	0.45	4.00	0.42	44	6	1	600	60	10
" 30....	43.00	0.49	4.00	0.41	39	7	1	550	55	15
May 1....	41.30	0.49	4.00	0.41	31	6	1	500	80	17
" 2....	42.40	0.49	4.00	0.41	24	5	1	500	80	19
" 3....	40.70	0.48	4.00	0.40	19	4	1	280	75	48
" 4....	33.80	0.47	4.00	0.39	16	3	1	400	80	9
" 5....	26.20	0.43	4.00	0.39	15	1	1		Sunday.	
" 6....	29.00	0.38	3.99	0.37	13	2	1	390	100	65
" 7....	27.60	0.36	.....	0.37	12	2	1	190	60	19
" 8....	24.70	0.31	3.99	0.37	10	2	1	.....	.....	.....
	Washed.									
" 9....	24.40	0.03	3.98	0.39	10	2	1	390	65	10
" 10....	24.80	0.04	4.00	0.42	10	2	1	300	80	18
" 11....	50.00	0.06	4.00	0.44	12	2	1	390	110	12
" 12....	50.00	0.08	4.00	0.48	17	2	1		Sunday.	
" 13....	50.00	0.09	4.00	0.47	35	3	1	600	100	18
" 14....	50.00	0.10	4.00	0.46	39	4	1	500	65	15
" 15....	48.50	0.15	4.00	0.45	17	3	1	500	70	16
" 16....	47.00	0.16	4.00	0.46	24	3	1	290	70	16
" 17....	47.00	0.16	3.99	0.47	18	3	1	260	40	9
" 18....	47.00	0.19	4.00	0.48	15	2	1	190	.....	17
" 19....	47.00	0.21	3.99	0.51	12	2	1		Sunday.	
" 20....	46.60	0.24	4.00	0.53	12	2	1	260	40	13
" 21....	46.40	0.24	4.00	0.55	16	2	1	260	65	9
" 22....	46.40	0.27	4.00	0.58	20	2	1	280	35	12
" 23....	46.40	0.29	4.00	0.61	15	2	1	130	35	10
" 24....	46.40	0.30	4.00	0.63	15	2	1	170	26	6
" 25....	46.40	0.32	4.00	0.66	15	2	1	340	80	13
" 26....	46.40	0.34	3.99	0.70	18	2	1		Sunday.	
" 27....	46.40	0.36	3.99	0.74	13	2	1	210	80	7
" 28....	46.40	0.38	3.15	0.76	16	2	1	260	70	10
" 29....	46.00	0.44	3.88	0.78	16	2	1	500	55	12
" 30....	45.60	0.46	3.99	0.86	14	2	1		Holiday.	
" 31....	45.60	0.46	4.00	0.92	17	2	1	380	65	11

TABLE 18.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
June 1.....	45.60	0.46	4.00	0.98	15	2	1	900	48	10
" 2.....	45.60	0.48	4.00	1.09	17	2	1		Sunday.	
" 3.....	45.60	0.51	4.00	1.20	24	2	1	550	75	16
" 4.....	45.60	0.54	4.00	1.32	37	3	1	6 500	.....	22
" 5.....	45.60	0.55	4.00	1.48	65	5	1	3 200	140	19
" 6.....	45.60	0.56	4.01	1.66	77	16	1	1 500	210	14
" 7.....	45.00	0.57	4.00	1.80	64	27	1	2 100	230	20
" 8.....	45.00	0.57	4.00	1.90	46	22	1	600	240	33
" 9.....	45.00	0.55	4.01	2.00	44	18	1		Sunday.	
" 10.....	45.00	0.56	4.00	2.09	36	12	1	240	110	43
" 11.....	45.00	0.58	4.60	2.17	30	8	1	280	130	60
" 12.....	45.00	0.60	4.01	2.27	34	8	1	330	150	60
" 13.....	45.00	0.62	4.00	2.36	35	10	1	480	....	120
" 14.....	45.00	0.63	3.99	2.49	31	9	1	440	....	65
" 15.....	45.00	0.64	3.99	2.56	32	8	1	420	....	49
" 16.....	44.70	0.65	4.00	2.63	26	7	1		Sunday.	
" 17.....	44.40	0.64	4.00	2.67	26	6	1	340	270	55
" 18.....	45.00	0.63	3.98	2.69	31	7	1	440	140	65
" 19.....	45.00	0.63	4.00	2.73	37	10	1	500	110	24
" 20.....	45.00	0.62	4.01	2.72	30	9	1	330	70	34
" 21.....	45.00	0.61	4.01	2.68	25	7	1	170	130	60
" 22.....	Shut down to scrape and apply asbestos and coke; removed 0.79 in. of sand.									
" 23.....	Applied 8 lb. of asbestos and 10 lb. of bone-charcoal.									
" 25.....	50.00	0.54	4.00	0.27	130	45	1	400	....	....
" 26.....	50.00	0.57	4.01	0.46	82	37	1	750	550	35
" 27.....	50.00	0.63	4.01	0.55	65	26	1	....	1 200	140
" 28.....	50.00	0.65	3.99	0.63	47	21	1	....	1 200	26
" 29.....	50.00	0.70	4.00	0.73	37	9	1	220	800	22
" 30.....	50.00	0.77	3.99	0.82	30	8	1		Sunday.	
July 1.....	50.00	0.87	4.00	0.80	30	8	1	400	90	37
" 2.....	50.00	0.95	4.01	0.73	32	9	1	180	230	25
" 3.....	50.00	1.01	4.00	0.66	36	10	1	350	80	58
" 4.....	50.00	1.03	4.00	0.58	44	12	1		Holiday.	
" 5.....	50.00	1.07	3.99	0.54	24	14	1	550	130	47
" 6.....	50.00	1.10	4.00	0.52	39	12	1	250	110	33
" 7.....	50.00	1.14	4.00	0.50	34	10	1		Sunday.	
" 8.....	50.00	1.16	4.00	0.48	25	7	1	220	190	14
" 9.....	50.00	1.18	4.00	0.46	22	5	1	50	30	3
" 10.....	50.00	1.20	3.99	0.45	47	11	1	Lost.	Lost.	Lost.
" 11.....	50.00	1.20	3.99	0.45	90	30	1	150	140	12
" 12.....	50.00	1.20	4.01	0.44	97	35	1	300	110	20
" 13.....	50.00	1.15	4.00	0.47	90	39	1	220	120	14
" 14.....	50.00	1.15	4.00	0.48	90	40	1		Sunday.	
" 15.....	50.00	1.14	3.99	0.48	95	40	1	375	320	19
" 16.....	50.00	1.19	4.00	0.48	120	45	1	Lost.	150	12
" 17.....	50.00	1.21	4.00	0.48	85	42	1	270	60	5
" 18.....	50.00	1.19	3.99	0.50	56	32	1	1 675	23	39
" 19.....	50.00	1.16	3.99	0.52	41	20	1	450	200	13
" 20.....	50.00	1.16	3.99	0.56	62	29	1	300	220	8
" 21.....	50.00	1.19	3.99	0.63	62	31	1		Sunday.	
" 22.....	50.00	1.20	3.99	0.77	80	36	1	1 400	700	9
" 23.....	50.00	1.21	3.99	0.93	105	40	1	3 700	370	25
" 24.....	50.00	1.18	3.99	1.07	95	40	1	770	260	31
" 25.....	50.00	1.17	3.99	1.22	77	32	1	250	230	3
" 26.....	50.00	1.07	4.00	1.37	67	29	1	140	90	12

TABLE 18.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
July 27....	50.00	1.11	4.00	1.51	54	25	1	300	180	6
" 28....	50.00	1.22	3.98	1.65	46	19	1	Sunday.		
" 29....	50.00	1.21	4.00	1.82	36	16	1	470	230	18
" 30....	50.00	1.20	3.99	1.98	29	11	1	Plates lost.		
" 31....	50.00	1.20	3.99	2.11	21	9	1	"	"	
Aug. 1....	51.00	1.21	3.96	2.27	16	6	1	Plates lost.		
" 2....	51.00	1.21	3.99	2.43	15	4	1	130	130	4
" 3....	51.00	1.21	4.00	2.66	16	3	1	120	80	4
" 4....	50.00	1.21	3.99	2.95	21	3	1	Sunday.		
" 5....	50.00	1.21	3.98	3.22	29	3	1	230	210	4
" 6....	50.00	1.22	3.98	3.50	34	4	1	85	320	19
" 7....	50.00	1.21	3.99	3.74	21	4	1	200	Lost.	19
" 8....	48.20	1.20	....	4.09	19	4	1	100	150	17
" 9....	50.00	1.18	....	4.45	16	3	1	75	220	9
" 10....	47.30	1.16	....	4.67	24	3	1	60	250	10
" 11....	Shut down to drain and scrape sand filter; 0.9 in. depth over all.									
" 16....	Out of service all the rest of month washing sponge and asbestos.									
Sept. 3....	50.00	0.02	4.00	0.16	12	5	1	300	.....	.....
" 4....	50.00	0.02	3.99	0.14	16	6	1	600	260	370
" 5....	50.00	0.02	4.01	0.13	34	6	1	360	71	165
" 6....	46.40	0.02	4.00	0.12	160	52	1	15 000	1 900	120
" 7....	50.00	0.03	4.00	0.11	64	26	1	2 000	170	62
" 8....	46.40	0.04	3.99	0.11	56	25	1	Sunday.		
" 9....	50.00	0.05	4.90	0.11	59	25	1	220	13	19
" 10....	50.00	0.05	4.00	0.11	57	21	1	18 000	100	24
" 11....	50.00	0.06	4.00	0.11	65	25	1	2 700	150	25
" 12....	50.00	0.07	4.00	0.12	72	26	1	1 000	190	36
" 13....	50.00	0.08	4.00	0.12	87	30	1	2 300	.....	35
" 14....	50.00	0.09	4.01	0.12	72	27	1	2 400	130	230
" 15....	48.20	0.11	4.00	0.12	65	25	1	Sunday.		
" 16....	51.00	0.13	4.00	0.12	65	25	1	Lost.	Lost.	27
" 17....	50.00	0.14	4.00	0.12	52	21	1	420	60	29
" 18....	49.10	0.14	4.00	0.13	60	18	1	900	80	41
" 19....	50.00	0.15	4.00	0.13	85	22	1	2 000	.....	19
" 20....	49.10	0.17	4.00	0.13	100	29	1	4 200	300	28
" 21....	49.10	0.18	4.00	0.13	120	34	1	1 100	160	30
" 22....	48.20	0.20	4.00	0.13	137	41	1	Sunday.		
" 23....	49.10	0.19	4.00	0.13	112	37	1	2 400	90	34
" 24....	46.40	0.19	3.99	0.14	100	35	1	4 000	210	12
" 25....	46.40	0.20	4.00	0.14	432	80	1	56 000	510	27
" 26....	45.60	0.24	4.00	0.15	385	80	4	1 300	450	55
" 27....	44.80	0.27	4.00	0.16	245	70	3	4 000	240	41
" 28....	46.40	0.30	3.99	0.16	127	46	2	15 000	430	37
" 29....	46.40	0.31	3.99	0.16	105	41	2	Sunday.		
" 30....	46.40	0.31	4.00	0.17	115	42	1	Lost.	1 600	110
Oct. 1....	48.20	0.33	4.00	0.18	82	36	1	600	600	120
" 2....	50.00	0.33	4.01	0.19	65	27	1	4 400	170	47
" 3....	48.20	0.33	4.00	0.19	59	24	1	900	210	44
" 4....	48.20	0.34	4.00	0.19	55	20	1	850	200	37
" 5....	50.00	0.38	4.00	0.19	9	21	1	2 000	150	34
" 6....	48.20	0.41	4.00	0.19	59	24	1	Sunday.		
" 7....	48.20	0.42	4.00	0.19	552	17	1	1 250	200	28
" 8....	50.00	0.42	4.00	0.19	54	16	1	11 000	210	28
" 9....	44.80	0.40	4.00	0.19	51	16	1	2 000	310	29

TABLE 18.—(*Continued.*)

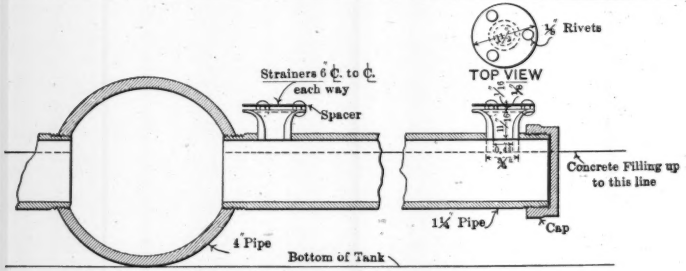
Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Oct. 10....	48.20	0.42	4.00	0.19	50	15	1	800	220	16
" 11....	48.20	0.43	4.00	0.20	47	13	1	2 000	310	46
	Washed.									
" 12....	50.00	0.14	4.00	0.20	36	11	1	1 200	370	25
" 13....	47.30	0.15	4.00	0.21	40	15	1		Sunday.	
" 14....	50.00	0.18	4.00	0.22	47	19	1	1 200	390	22
" 15....	53.00	0.20	4.00	0.23	41	16	1	900	140	16
" 16....	50.00	0.20	4.00	0.24	35	12	1	Lost.	310	18
" 17....	50.00	0.21	4.00	0.25	30	8	1	550	180	7
" 18....	50.00	0.21	4.00	0.25	25	6	1	260	100	33
" 19....	50.00	0.21	4.00	0.25	25	6	1	750	220	15
" 20....	50.00	0.22	4.00	0.25	20	5	1		Sunday.	
" 21....	50.00	0.23	4.00	0.25	19	5	1	480	120	11
" 22....	50.00	0.24	4.00	0.26	18	4	1	280	70	7
" 23....	50.00	0.25	4.00	0.26	15	3	1	250	120	12
" 24....	50.00	0.26	4.00	0.26	15	3	1	300	80	12
" 25....	50.00	0.27	4.00	0.27	15	2	1	450	60	15
" 26....	50.00	0.28	4.00	0.27	15	2	1	450	Lost.	14
" 27....	50.00	0.29	4.00	0.27	13	2	0		Sunday.	
" 28....	50.00	0.30	4.00	0.27	13	2	0	190	110	9
" 29....	50.00	0.31	4.00	0.27	25	2	0	880	.....	.....
" 30....	50.00	0.32	4.00	0.27	21	3	0	.....	.....	.....
" 31....	Out of commission, 4-in. supply pipe stopped up.									
Nov. 4....	50.00	0.16	4.00	0.28	125	11	1	.....	.....	.....
" 5....	50.00	0.17	4.00	0.28	185	61	1	6 000	3 000	220
" 6....	50.00	0.18	4.00	0.29	170	66	1	5 000	1 100	150
" 7....	50.00	0.20	4.00	0.30	100	45	1	14 000	1 600	120
" 8....	50.00	0.21	4.00	0.32	95	42	1	1 900	2 000	29
" 9....	50.00	0.22	4.00	0.34	80	36	1	4 000	2 000	110
" 10....	50.00	0.23	4.00	0.36	67	29	1		Sunday.	
" 11....	50.00	0.24	3.46	0.38	52	20	1	1 900	460	160
" 12....	50.00	0.26	3.99	0.40	40	13	1	7 500	1 100	110
" 13....	50.00	0.27	4.00	0.44	36	10	1	1 600	550	50
" 14....	50.00	0.28	4.00	0.49	42	13	1	2 700	950	48
" 15....	50.00	0.29	4.00	0.55	35	11	1	1 800	900	49
" 16....	50.00	0.30	4.00	0.65	26	7	1	1 100	360	35
" 17....	50.00	0.31	3.98	0.80	20	5	1		Sunday.	
" 18....	50.00	0.32	3.99	0.98	17	4	1	1 600	200	35
" 19....	50.00	0.34	3.99	1.26	16	3	1	1 300	400	55
" 20....	50.00	0.35	3.98	1.64	45	4	1	6 500	3 500	200
" 21....	50.00	0.36	3.99	2.08	52	12	1	9 900	4 500	130
" 22....	50.00	0.37	3.98	2.33	65	24	1	10 000	5 500	220
" 23....	50.00	0.38	3.99	2.60	49	19	1	18 000	3 500	100
" 24....	50.00	0.40	3.98	2.85	134	32	1		Sunday.	
" 25....	48.20	0.45	3.98	3.10	225	87	2	50 000	19 000	340
" 26....	50.00	0.49	3.98	3.62	237	90	2	40 000	11 000	220
" 27....	50.00	0.51	3.99	4.15	185	77	2	16 000	7 500	310
" 28....	50.00	0.54	3.84	4.44	130	57	2		Holiday.	
" 29....	50.00	0.55	3.67	4.55	80	36	1	10 000	2 200	80
" 30....	50.00	0.56	3.44	4.65	54	25	1	3 800	2 200	55
Dec. 2....	Shut down to scrape sand filter.									
" 6....	50.00	0.64	4.00	0.46	16	3	1	.....	.....	.....
" 7....	50.00	0.64	4.00	0.39	14	3	1	2 400	1 200	490
" 8....	50.00	0.64	4.01	0.35	12	2	1		Sunday.	
" 9....	50.00	0.65	4.01	0.33	11	2	1	1 200	420	60

TABLE 18.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1907.										
Dec. 10....	50.00	0.65	4.00	0.33	12	2	1	800	950	66
" 11....	47.30	0.64	4.00	0.35	255	84	3	6 500	1 600	140
" 12....	46.40	0.70	3.98	0.39	212	100	6	48 000	15 000	1 800
" 13....	50.00	0.79	3.98	0.49	495	217	9	42 000	20 000	1 600
" 14....	52.00	0.84	3.97	0.65	357	167	9	49 000	9 500	1 200
" 15....	49.10	0.84	3.98	0.77	157	76	6		Sunday.	
" 16....	49.10	0.86	3.97	0.84	90	42	4	19 000	800	706
" 17....	49.10	0.88	3.98	0.91	70	31	2	21 000	18 000	1 600
" 18....	48.20	0.89	3.98	0.94	49	21	2	6 500	7 000	600
" 19....	50.00	0.91	3.98	0.97	39	13	1	Lost.	Lost.	Lost.
" 20....	49.10	0.92	3.98	1.03	42	16	1	"	"	"
" 21....	50.00	0.94	3.98	1.08	26	7	1	"	"	"
" 22....	50.00	0.97	3.98	1.13	20	5	1		Sunday.	
" 23....	50.00	0.95	3.98	1.19	34	9	1	1 400	500	160
" 24....	47.30	0.93	3.98	1.28	195	75	2	9 000	1 700	130
" 25....	44.10	0.91	3.97	1.47	445	210	9		Holiday.	
" 26....	46.40	1.01	3.97	1.63	370	172	7	51 000	8 000	250
" 27....	50.00	1.11	3.98	1.81	245	110	5	55 000	5 600	210
" 28....	48.20	1.12	3.99	1.87	102	46	3	10 000	4 500	140
" 29....	50.00	1.14	3.99	1.85	75	32	2		Sunday.	
" 30....	49.10	1.15	3.98	1.86	56	24	2	4 400	1 900	190
" 31....	50.00	1.17	4.00	1.87	39	15	1	14 000	1 300	60
1908.										
Jan. 1....	50.00	1.18	3.98	1.90	31	8	1	.....	.....	.....
" 2....	50.00	1.18	3.99	1.94	39	11	1	4 400	750	45
" 3....	50.00	1.19	3.98	1.98	36	11	1	3 100	1 600	70
	Washed.									
" 4....	50.00	0.17	3.97	2.09	32	9	1	2 400	1 200	43
" 5....	50.00	0.18	3.98	2.22	26	6	1		Sunday.	
" 6....	50.00	0.19	3.98	2.28	20	5	1	600	600	49
" 7....	50.00	0.20	3.98	2.37	20	5	1	1 100	330	49
" 8....	50.00	0.21	3.99	2.43	22	5	1	1 900	900	43
" 9....	50.00	0.23	3.98	2.52	45	13	1	13 000	3 400	50
" 10....	50.00	0.24	3.99	2.66	70	30	1	10 000	8 000	50
" 11....	50.00	0.27	3.98	2.74	56	22	1	16 000	220	200
" 12....	50.00	0.28	3.98	2.83	40	12	1		Sunday.	
" 13....	49.10	0.30	3.98	2.93	110	51	2	8 500	1 200	43
" 14....	48.20	0.33	3.99	3.04	210	113	4	16 000	6 000	280
" 15....	46.40	0.35	3.98	3.21	325	222	15	24 000	9 500	700
" 16....	50.00	0.40	3.98	3.49	360	247	42	28 000	14 000	900
" 17....	50.00	0.43	3.98	3.86	242	147	26	65 000	20 000	1 200
" 18....	50.00	0.46	3.91	3.99	137	73	7	7 000	6 500	400
" 19....	.....	....	....	....	...	...	..		Sunday.	
" 20....	Scraped.									
" 21....	50.00	0.48	3.00	0.76	55	25	4	.....	.....	.....
" 22....	50.00	0.48	3.01	0.60	49	21	4	3 600	1 900	150
" 23....	50.00	0.49	3.00	0.57	40	15	3	1 800	700	170
" 24....	50.00	0.49	2.99	0.60	40	13	3	2 300	950	90
" 25....	50.00	0.50	2.99	0.65	39	12	3	1 100	800	95
" 26....	50.00	0.50	2.98	0.69	32	9	2		Sunday.	
" 27....	50.00	0.51	2.99	0.76	32	9	2	300	700	70
" 28....	50.00	0.52	2.99	0.82	45	15	2	1 200	900	70
" 29....	50.00	0.55	2.99	0.90	60	26	2	1 000	1 400	95
" 30....	50.00	0.57	2.98	0.98	57	27	2	1 400	210	33
" 31....	50.00	0.58	2.98	1.08	42	18	2	1 100	750	45

TABLE 18.—(*Continued.*)

Date.	Preliminary filter.		Final filter.		Turbidity.			Bacteria.		
	Rate, millions of gallons per acre daily.	Loss of head.	Rate, millions of gallons per acre daily.	Loss of head.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.	Applied water.	Effluent, preliminary filter.	Effluent, final filter.
1908.										
Feb. 1....	50.00	0.59	2.99	1.16	39	14	2	750	1 000	70
" 2....	49.10	0.60	2.99	1.22	27	9	2		Sunday.	
" 3....	49.10	0.61	2.98	1.30	29	8	2	1 300	750	20
" 4....	50.00	0.64	2.99	1.40	25	6	2	600	900	60
" 5....	50.00	0.66	2.99	1.50	24	6	2	750	1 200	75
" 6....	50.00	0.67	2.99	1.55	20	5	2	2 000	800	60
" 7....	50.00	0.68	3.00	1.56	17	4	1	.....	600	34
" 8....	50.00	0.69	3.00	1.53	15	4	1	900	220	35
" 9....	50.00	0.71	3.00	1.54	14	4	1		Sunday.	
" 10....	50.00	0.72	2.99	1.60	11	4	1	850	500	28
" 11....	50.00	0.74	2.99	1.62	10	4	1	1 000	500	23
" 12....	50.00	0.75	2.98	1.68	8	4	1	750	290	18
" 13....	50.00	0.76	2.99	1.74	9	4	1	700	260	10
" 14....	48.20	0.76	2.99	1.77	9	4	1	1 200	250	27
" 15....	51.80	0.79	2.99	1.89	61	18	1	5 500	4 800	13
" 16....	48.20	0.79	2.99	2.08	80	40	2		Sunday.	
" 17....	48.20	0.81	2.99	2.24	80	40	3	33 000	1 300	60
" 18....	47.30	0.82	2.99	2.31	130	65	3	.....	950	120
" 19....	51.80	0.92	2.99	2.45	320	200	7	28 000	22 000	360
" 20....	52.70	0.99	2.99	2.61	177	97	9	22 000	16 300	350
" 21....	51.80	1.03	2.99	2.68	105	52	6	10 600	3 800	270
" 22....	50.90	1.07	2.99	2.72	85	42	5		Holiday.	
" 23....	50.00	1.09	2.99	2.76	60	30	4		Sunday.	
" 24....	51.80	1.12	2.99	2.80	46	19	3	3 600	1 700	120
" 25....	50.00	1.14	2.99	2.84	31	9	2	2 300	1 300	60
" 26....	50.00	1.17	3.00	2.87	30	8	2	3 800	1 300	43
" 27....	48.20	1.18	2.99	2.90	30	7	1	1 300	900	42
" 28....	47.30	1.19	2.99	2.94	37	7	1	1 400	800	31
" 29....	51.80	1.23	2.99	3.01	123	49	2	13 500	750	35
Mar. 1....	48.20	1.20	2.98	2.99	97	44	5		Sunday.	
" 2....	50.00	1.28	2.99	3.12	82	35	4	8 000	2 500	70
" 3....	50.90	1.32	2.98	3.22	87	38	4	11 000	6 000	55
" 4....	50.00	1.33	2.99	3.28	67	29	3	6 000	1 400	38
" 5....	50.00	1.35	2.99	3.32	59	23	3	4 400	2 500	37
" 6....	Discontinued; sand filter being used for sedimentation experiments.									



DETAIL OF STRAINER SYSTEM

FIG. 9.

TABLE 19.—RECORD OF EXPERIMENTAL FILTER PLANT NO. 3.

Date.	Sand Filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
Feb. 12	2.99	0.18	14	..	2	.....	.....	.....	.....
" 13	3.00	0.17	15	..	2	600	.....	.....	.....
" 14	3.19	0.18	15	..	2	650	.....	.....	.....
" 15	3.86	0.22	12	..	2	600	.....	2 500	.....
" 16	3.84	0.29	14	..	2	850	.....	1 600	.....
" 17	....	....	....	..	..	.....	.....	.....	.....
" 18	....	....	....	..	..	1 200	.....	300	.....
" 21	3.91	0.32	20	..	2	1 800	.....	550	.....
" 22	3.95	0.39	15	..	2		Holiday.		
" 23	3.94	0.43	20	..	3	1 600	.....	1 100	.....
" 24	3.89	0.47	20	..	3		Sunday.		
" 25	4.19	0.52	20	..	3	1 400	.....	600	.....
" 26	4.13	0.57	20	..	3	700	.....	650	.....
" 27	3.32	0.62	17	..	3	700	.....	2 800	.....
" 28	4.41	0.67	15	..	3	800	.....	550	.....
Mar. 1	3.91	0.72	15	..	3	650	.....	300	.....
" 2	3.93	0.79	15	..	3	1 000	.....	270	.....
" 3	3.90	0.82	31	..	3		Sunday.		
" 4	3.92	0.80	35	..	3	1 200	.....	140	1.45
" 5	3.96	0.98	135	..	4	13 000	.....	190	1.94
" 6	4.05	1.25	135	29	2	18 000	2 100	160	2.08
" 7	3.95	1.52	102	15	1	24 000	3 500	160	1.50
" 8	3.90	1.67	100	15	1	22 000	1 800	130	1.38
" 9	3.93	1.80	90	15	1	24 000	3 500	130	1.37
" 10	3.95	1.91	82	16	1		Sunday.		1.36
" 11	3.96	2.08	68	18	1	18 000	6 000	120	1.24
" 12	4.02	2.19	46	18	1	11 000	9 000	140	1.08
" 13	4.02	2.31	40	15	1	9 000	5 000	120	0.94
" 14	3.96	2.44	39	16	1	5 500	3 600	90	0
" 15	4.07	2.42	35	20	1	6 500	3 800	85	0
" 16	3.85	2.20	60	29	1	5 000	3 500	100	1.26
" 17	3.95	2.21	135	25	1		Sunday.		1.52
" 18	3.88	2.86	170	25	1	9 000	1 900	85	1.75
" 19	3.82	3.31	125	21	1	7 000	700	65	1.57
" 20	3.78	3.47	102	20	1	4 800	1 500	60	1.31
" 21	3.71	3.70	125	20	1	8 500	1 500	70	1.38
" 22	3.64	3.81	190	25	1	7 500	1 100	35	1.57
" 23	3.58	3.95	180	26	1	7 500	470	55	1.68
" 24	3.46	4.18	140	19	1		Sunday.		1.52
" 25	Scraped, 1.03 in. of sand removed.								
" 27	4.06	0.22	47	8	1	2 200	480	60	1.08
" 28	4.02	0.37	35	..	0	1 300	250	80	1.00
" 29	4.02	0.46	26	..	..	700	240	65	0
" 30	Shut down to fill coagulant basin.								
" 31	....	....	25	..	..	310	.....	.....	0
	4.00	0.45	21	15	1		Sunday.		0
Apr. 1	3.39	0.42	20	15	1	600	1 000	43	0
" 2	3.06	0.46	24	17	1	270	Lost.	35	0
" 3	3.01	0.49	24	17	1	460	"	41	0
" 4	2.95	0.50	20	15	1	280	550	27	0
" 5	2.95	0.51	20	13	1	450	1 000	60	0
" 6	2.96	0.49	20	12	1	320	50	35	0
" 7	2.99	0.48	20	12	1		Sunday.		0
" 8	3.01	0.49	18	12	1	330	650	22	0
" 9	3.01	0.55	18	12	1	140	750	21	0
" 10	3.02	0.57	30	15	0	750	5 000	29	0
" 11	3.04	0.61	66	16	0	4 000	550	25	1.11
" 12	3.09	0.72	72	13	0	14 000	2 200	17	1.15
" 13	3.07	0.88	80	19	0	13 000	3 900	25	1.14

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
Apr. 14	2.98	1.04	77	18	1		Sunday.		1.17
" 15	2.97	1.20	62	18	1	7 000	2 200	19	1.09
" 16	3.01	1.32	47	17	1	3 600	900	22	1.08
" 17	3.05	1.44	39	19	0	1 600	1 100	12	0
" 18	3.04	1.41	30	20	1	1 810	1 870	14	0
" 19	3.04	1.35	25	18	1	790	910	14	0
" 20	3.07	1.30	20	15	1	540	480	15	0
" 21	3.07	1.26	20	15	1		Sunday.		..
" 22	3.04	1.21	18	12	0	235	420	21	0
" 23	3.06	1.22	15	10	0	170	420	8	0
" 24	2.99	1.26	19	10	0	150	250	17	0
" 25	3.04	1.27	34	12	0	700	260	19	0
" 26	3.07	1.28	46	12	0	1 200	320	80	0
" 27	2.94	1.49	52	..	0	1 700	1 500	70	0
" 28	2.96	1.88	45	..	1		Sunday.		0
" 29	2.99	2.40	44	33	1	600	1 400	19	0
" 30	3.00	2.83	39	29	1	550	1 200	14	0
May 1	3.01	2.71	31	21	1	500	1 300	20	0
" 2	3.01	2.51	24	15	1	500	850	16	0
" 3	3.00	2.36	19	12	1	280	650	34	0
" 4	3.01	2.29	16	10	0	400	550	24	0
" 5	3.01	2.25	15	9	0		Sunday.		0
" 6	3.06	2.32	13	8	0	390	460	80	0
" 7	2.96	2.46	12	7	0	190	.....	18	0
" 8	3.00	2.51	10	5	0	.....	.....	.....	0
" 9	3.03	2.77	10	5	0	390	1 100	14	0
" 10	3.01	2.87	10	5	0	300	500	21	0
" 11	2.99	3.16	12	6	0	390	650	16	0
" 12	3.00	3.34	17	7	0		Sunday.		0
" 13	3.00	3.44	35	9	0	600	470	27	0
" 14	3.01	3.46	39	12	0	500	550	25	0
" 15	3.01	3.56	17	..	0	500	900	23	0
" 16	2.93	4.07	24	..	0	290	2 500	25	0
" 17	3.01	4.34	18	..	0	260	2 000	16	0
" 18	2.93	4.25	15	8	0	190	600	19	0
" 19	2.97	4.36	12	8	0		Sunday.		0
" 20	3.01	4.64	12	8	0	260	450	15	0
" 21	2.99	4.55	16	8	0	260	330	14	0
" 22	3.01	4.57	20	8	0	280	390	22	0
" 23	3.00	4.51	15	8	0	130	240	19	0
" 24	2.98	4.44	15	8	0	170	240	30	0
" 25	3.00	4.38	15	8	0	340	400	41	0
" 26	3.00	4.38	18	8	0		Sunday.		0
" 27	Shut down to scrape sand filter; 1.09 in. of sand removed. Cleaning coagu								
" 28	lant basin and treating coagulant basin with 1:2 000 000 solution of copper								
" 29	sulphate.		16	..	..	.....	.....	.....	.....
" 30	3.00	0.11	14	8	1		Holiday.		0
" 31	3.01	0.10	17	8	1	380	18 000	150	0
June 1	3.01	0.09	15	8	1	900	7 000	150	0
" 2	3.01	0.10	17	8	1		Sunday.		0
" 3	3.01	0.10	24	10	1	550	8 000	130	0
" 4	3.04	0.11	37	13	1	6 500	7 500	140	0
" 5	3.00	0.11	65	29	1	3 200	3 000	110	0
" 6	3.00	0.11	77	46	1	1 500	800	60	1.17
" 7	2.99	0.12	64	21	1	2 100	1 500	90	1.18
" 8	2.98	0.17	46	22	1	600	1 000	60	0
" 9	3.00	0.18	44	30	1		Sunday.		0
" 10	3.01	0.18	36	26	1	2 40	400	32	0

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
June 11	3.00	0.17	30	20	1	250	300	31	0
" 12	3.00	0.17	34	22	1	330	.....	28	0
" 13	2.99	0.17	35	25	1	480	480	39	0
" 14	2.98	0.17	31	22	1	440	550	32	0
" 15	2.99	0.19	32	22	1	420	450	27	0
" 16	3.02	0.21	26	18	1		Sunday.		0
" 17	2.99	0.23	26	16	1	340	750	14	0
" 18	3.02	0.25	31	20	1	440	750	21	0
" 19	3.02	0.29	37	27	1	500	460	35	0
" 20	3.00	0.32	30	21	1	330	440	38	0
" 21	3.01	0.36	25	16	1	170	370	23	0
" 22	3.00	0.40	20	12	1	100	300	17	0
" 23	2.97	0.43	26	11	1		Sunday.		0
" 24	2.97	0.44	140	36	1	1 700	350	22	1.59
" 25	3.02	0.45	130	27	1	400	250	16	1.55
" 26	Interrupted, defective meter.					750	330	.....	0
" 27	3.00	0.43	65	15	0	.....	1 400	.....	0
" 28	3.00	0.44	47	19	0	.....	1 400	120	0
" 29	2.99	0.44	37	20	0	220	300	.....	0
" 30	2.97	0.42	30	19	0		Sunday.		0
July 1	2.99	0.37	30	18	0	400	600	85	0
" 2	3.01	0.33	32	19	0	180	1 000	50	0
" 3	3.00	0.31	36	21	0	350	310	21	0
" 4	3.00	0.30	44	30	0		Holiday.		
" 5	3.00	0.29	44	35	0	550	400	41	0
" 6	3.00	0.28	39	30	0	250	280	22	0
" 7	3.00	0.28	34	24	0		Sunday.		0
" 8	3.00	0.28	25	16	0	220	260	27	0
" 9	3.00	0.27	22	13	0	50	40	19	0
" 10	2.98	0.27	47	27	1	Lost.	Lost.	Lost.	0
" 11	3.00	0.27	90	41	1	150	50	8	1.27
" 12	3.00	0.29	97	21	1	300	200	13	1.27
" 13	3.00	0.34	90	20	0	220	160	17	1.27
" 14	3.00	0.40	90	19	0		Sunday.		1.27
" 15	3.00	0.54	95	18	0	375	150	.....	1.27
" 16	3.00	0.59	120	20	0	Lost.	50	Lost.	1.36
" 17	3.00	0.58	85	16	0	270	60	3	1.26
" 18	2.99	0.61	56	13	0	1 675	70	.....	1.17
" 19	3.01	0.61	41	18	0	450	700	11	0
" 20	2.99	0.51	62	27	0	300	720	8	0
" 21	3.00	0.47	62	32	0		Sunday.		0
" 22	3.00	0.47	80	34	0	1 400	560	14	1.17
" 23	3.01	0.49	105	21	0	3 700	490	40	1.25
" 24	3.01	0.60	95	19	0	770	110	80	1.27
" 25	3.00	0.68	77	16	0	250	80	5	1.22
" 26	2.99	0.68	67	17	0	140	40	4	0
" 27	3.00	0.69	54	20	0	300	130	21	0
" 28	3.00	0.72	46	27	0		Sunday.		0
" 29	3.00	0.74	36	26	0	470	290	100	0
" 30	2.99	0.76	29	19	0	Lost.	Lost.	Lost.	0
" 31	2.99	0.77	21	12	0	"	"	"	0
Aug. 1	3.00	0.75	16	9	0	Lost.	Lost.	Lost.	0
" 2	3.00	0.74	15	8	0	130	140	4	0
" 3	3.00	0.74	16	7	0	120	180	6	0
" 4	3.00	0.75	21	6	0		Sunday.		
" 5	3.00	0.76	29	8	0	230	100	44	0
" 6	3.00	0.79	34	12	0	85	470	.....	0
" 7	2.99	1.01	21	12	0	200	450	.....	0
" 8	3.00	1.31	19	11	0	100	180	45	0

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
Aug. 9.....	2.98	1.44	16	9	0	75	80	16	0
" 10.....	3.00	1.44	24	9	0	60	90	11	0
" 11.....	3.00	1.49	62	22	0		Sunday.		
" 12.....	3.00	1.62	120	39	0	620	260	16	1.45
" 13.....	2.97	2.06	107	22	0	820	520	10	1.38
" 14.....	2.97	3.06	82	19	0	850	120	26	1.22
" 15.....	2.81	3.91	65	15	0	150	260	6	1.17
" 16.....	3.00	4.29	45	18	0	270	340	17	0
" 17.....	3.00	3.86	35	22	0	340	200	13	0
" 18.....	3.00	3.47	21	13	0		Sunday.		0
" 19.....	3.00	3.49	18	10	0	180	220	17	0
" 20.....	3.00	3.56	20	8	0	210	180	16	0
" 21.....	3.00	3.58	20	10	0	1 300	650	8	0
" 22.....	2.99	3.73	27	13	0	3 800	360	6	0
" 23.....	3.00	4.00	49	34	0	2 500	700	10	0
" 24.....	3.00	4.05	36	26	0	3 900	630	12	0
" 25.....	2.98	4.06	34	24	0		Sunday.		0
" 26.....	3.00	4.20	21	13	0	700	310	16	0
" 27.....	3.00	4.31	19	11	0	470	250	12	0
" 28.....	2.99	4.40	18	10	0	500	160	18	0
" 29.....	3.01	4.41	17	9	0	360	110	9	0
" 30.....	2.98	4.46	15	8	0	320	310	14	0
" 31....	Scraped. 1.88 in. of sand removed.		13	..	..	200	100	.....	0
Sept. 5.....	3.00	0.10	34	4	0	360	950	.....	1.04
" 6.....	3.00	0.10	160	3	0	15 000	1 500	190	1.35
" 7.....	3.00	0.09	64	3	0	2 000	260	100	1.20
" 8.....	3.00	0.08	56	4	0		Sunday.		1.04
" 9.....	3.00	0.08	59	3	0	220	180	38	1.04
" 10.....	2.97	0.07	57	3	0	18 000	150	29	1.06
" 11.....	2.98	0.07	65	2	0	2 700	200	37	1.04
" 12.....	2.98	0.08	72	2	0	1 000	125	19	1.04
" 13.....	3.00	0.08	87	3	0	2 300	200	72	1.20
" 14.....	3.00	0.08	72	3	0	2 400	360	36	1.12
" 15.....	3.00	0.08	65	3	0		Sunday.		1.04
" 16.....	3.00	0.08	65	2	0	Lost.	Lost.	38	1.04
" 17.....	3.00	0.08	52	2	0	420	200	38	1.07
" 18.....	3.00	0.08	60	2	0	900	200	17	1.07
" 19.....	2.98	0.08	85	2	0	2 000	220	25	1.12
" 20.....	2.98	0.09	100	2	0	4 200	320	31	1.24
" 21.....	2.99	0.09	120	3	0	1 100	160	19	1.33
" 22.....	3.00	0.09	137	3	0		Sunday.		1.45
" 23.....	3.02	0.09	112	4	0	2 400	190	15	1.41
" 24.....	3.00	0.10	100	4	0	4 000	620	13	1.33
" 25.....	3.00	0.11	432	3	0	56 000	290	7	1.83
" 26.....	2.99	0.11	385	2	0	1 300	950	19	2.34
" 27.....	3.00	0.12	245	4	0	4 000	Lost.	20	1.91
" 28.....	2.98	0.13	127	4	0	15 000	1 000	8	1.54
" 29.....	2.98	0.14	105	4	0		Sunday.		1.34
" 30.....	2.99	0.15	115	3	0	Lost.	Lost.	46	1.35
Oct. 1.....	3.00	0.15	82	3	0	600	1 700	22	1.24
" 2.....	2.98	0.16	65	3	0	4 400	550	8	1.09
" 3.....	3.00	0.17	59	2	0	900	330	15	1.04
" 4.....	2.99	0.17	55	2	0	850	250	11	1.03
" 5.....	2.99	0.19	59	2	0	2 000	450	25	1.04
" 6.....	2.98	0.20	59	2	0		Sunday.		1.04
" 7.....	2.98	0.21	52	2	0	1 250	2 300	42	1.04
" 8.....	2.97	0.21	54	2	0	11 000	100	15	1.04

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
Oct. 9	2.98	0.22	51	2	0	2 000	1 600	7	1.04
" 10	2.98	0.24	50	2	0	800	Lost.	24	1.04
" 11	2.98	0.25	47	2	0	2 000	1 200	21	0
" 12	2.97	0.26	36	3	0	1 200	1 200	19	0
" 13	2.98	0.27	40	4	0		Sunday.		0
" 14	2.98	0.29	47	5	0	1 200	830	25	0
" 15	2.99	0.31	41	5	0	900	Lost.	105	0
" 16	2.99	0.32	35	4	0	Lost.	550	19	0
" 17	2.98	0.34	30	4	0	550	800	21	0
" 18	3.00	0.35	25	4	0	260	350	9	0
" 19	3.00	0.35	25	4	0	750	310	35	0
" 20	3.00	0.35	20	3	0		Sunday.		0
" 21	3.00	0.35	19	3	0	480	540	35	0
" 22	2.99	0.36	18	3	0	230	440	17	0
" 23	2.99	0.37	15	3	0	250	440	39	0
" 24	2.98	0.38	15	3	0	300	500	60	0
" 25	2.99	0.39	15	3	0	450	410	65	0
" 26	2.99	0.40	15	3	0	450	500	44	0
" 27	2.99	0.41	13	2	0		Sunday.		0
" 28	2.99	0.43	13	2	0	190	500	50	0
" 29	2.98	0.44	25	2	0	380	60	75	0
" 30	2.99	0.46	21	2	0	450	180	3	0
" 31	2.96	0.48	25	3	0	2 300	390	75	0
Nov. 4	3.00	0.51	125	2	0	.....	.....	.....	0
" 5	3.00	0.53	185	2	0	6 000	1 600	90	1.70
" 6	2.99	0.56	170	2	0	5 000	3 900	6	1.70
" 7	2.99	0.60	100	3	0	14 000	300	9	1.48
" 8	2.99	0.64	95	3	0	1 900	230	2	1.27
" 9	2.99	0.70	80	4	0	4 000	2 700	203	0
" 10	2.99	0.79	67	4	0		Sunday.		0
" 11	2.99	1.00	52	6	0	1 900	2 000	200	0
" 12	2.99	1.46	40	9	0	7 500	2 300	160	0
" 13	2.98	2.09	36	10	0	1 600	1 100	170	0
" 14	2.99	2.74	42	9	0	2 700	950	130	0
" 15	2.99	2.98	35	8	0	1 800	800	11	0
" 16	2.99	3.03	26	8	0	1 100	800	90	0
" 17	3.00	3.07	20	6	0		Sunday.		0
" 18	3.00	3.09	17	5	0	1 600	700	100	0
" 19	2.99	3.13	16	4	0	1 300	600	60	0
" 20	2.99	3.17	45	3	0	6 500	120	120	0
" 21	2.99	3.22	52	3	0	9 900	1 000	80	0
" 22	2.99	3.27	65	5	0	10 000	3 200	90	0
" 23	2.99	3.33	49	8	0	18 000	2 400	100	0
" 24	2.99	3.41	134	11	0		Sunday.		0
" 25	2.98	3.54	225	12	1	50 000	2 100	65	1.68
" 26	2.98	3.68	237	13	1	40 000	2 400	95	1.76
" 27	2.99	3.96	185	16	1	16 000	2 600	60	1.74
" 28	2.98	4.29	130	18	1		Holiday.		1.57
" 29	2.97	4.48	80	19	1	10 000	2 500	65	1.50
" 30	2.97	4.54	54	15	1	3 800	1 900	85	0
Dec. 6	Scraped, 1.62 in. of sand removed.								
" 8	2.97	0.16	12	3	0		Sunday.		1.17
" 9	2.98	0.16	11	3	0	1 200	410	10	1.17
" 10	2.98	0.15	12	3	0	800	550	150	1.17
" 11	2.99	0.15	255	3	0	6 500	600	130	1.52
" 12	3.00	0.13	212	2	0	48 000	500	130	1.99
" 13	2.98	0.13	495	4	0	42 000	500	120	2.06
" 14	2.99	0.14	357	5	0	49 000	750	150	2.12
" 15	2.99	0.15	157	6	0		Sunday.		1.69

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1907.									
Dec. 16.....	2.98	0.16	90	9	0	19 000	900	20	1.28
" 17.....	2.98	0.20	70	12	0	21 000	400	170	1.17
" 18.....	2.98	0.24	49	12	1	6 500	7 000	350	1.17
" 19.....	2.98	0.29	39	9	1	Lost.	Lost.	Lost.	1.17
" 20.....	2.98	0.36	42	7	1	"	"	"	1.17
" 21.....	2.97	0.45	26	5	0	"	"	"	1.17
" 22.....	2.98	0.57	20	4	0		Sunday.		1.17
" 23.....	2.98	0.71	34	3	0	1 400	1 300	220	1.17
" 24.....	2.98	0.83	195	2	0	9 000	1 000	140	1.49
" 25.....	2.98	0.97	445	2	0		Holiday.		2.43
" 26.....	2.98	1.11	370	2	0	51 000	1 000	39	2.15
" 27.....	2.98	1.27	245	3	0	55 000	1 600	70	1.91
" 28.....	2.98	1.40	102	4	0	10 000	1 000	80	1.50
" 29.....	2.98	1.60	75	3	0		Sunday.		1.21
" 30.....	2.97	1.85	56	3	0	4 400	700	80	1.17
" 31.....	2.98	2.07	39	2	0	14 000	1 200	65	1.17
1908.									
Jan. 1.....	2.99	2.11	31	2	0		Holiday.		1.17
" 2.....	2.98	2.17	39	2	0	4 400	700	19	1.17
" 3.....	2.98	2.26	36	2	0	3 100	1 000	13	1.17
" 4.....	2.98	2.34	32	2	0	2 400	550	19	1.17
" 5.....	2.98	2.41	26	2	0		Sunday.		1.17
" 6.....	2.98	2.49	20	2	0	600	230	18	1.17
" 7.....	2.98	2.58	20	2	0	1 100	370	12	1.17
" 8.....	2.99	2.61	22	2	0	1 900	1 100	20	1.17
" 9.....	2.99	2.63	45	2	0	13 000	1 200	22	1.21
" 10.....	2.98	2.67	70	2	0	10 000	700	16	1.17
" 11.....	2.98	2.72	56	2	0	16 000	1 200	11	1.17
" 12.....	2.98	2.78	40	2	0		Sunday.		1.17
" 13.....	2.98	2.84	110	2	0	8 500	90	6	1.27
" 14.....	2.98	2.95	210	2	0	16 000	150	23	1.56
" 15.....	2.98	3.07	325	3	0	24 000	1 100	19	1.92
" 16.....	2.98	3.23	360	5	6	28 000	1 000	14	2.10
" 17.....	2.97	3.73	242	6	0	65 000	490	23	1.91
" 18.....	2.98	4.42	137	6	0	7 000	1 600	14	1.66
" 19.....	2.99	4.75	117	5	0		Sunday.		1.50
" 21.....	Scraped, 1.45 in. of sand removed.								
" 23.....	3.00	0.14	40	3	0	.....	.....	.....	1.17
" 24.....	3.00	0.14	40	3	0	2 300	550	55	1.17
" 25.....	3.00	0.13	39	3	0	1 100	850	95	0
" 26.....	3.00	0.13	32	3	0		Sunday.		0
" 27.....	3.00	0.13	32	2	0	300	280	60	0
" 28.....	2.99	0.15	45	3	0	1 200	700	70	0
" 29.....	2.99	0.20	60	6	1	1 000	900	75	0
" 30.....	2.99	0.24	57	8	1	1 400	650	50	0
" 31.....	2.99	0.30	42	6	1	1 100	600	36	0
Feb. 1.....	2.99	0.34	39	5	1	750	50	25	0
" 2.....	2.99	0.41	27	4	1		Sunday.		0
" 3.....	2.99	0.51	29	3	0	1 300	220	16	0
" 4.....	2.99	0.56	25	3	0	600	370	10	0
" 5.....	2.99	0.58	24	4	0	750	700	21	0
" 6.....	2.99	0.61	20	6	0	2 000	650	4	0
" 7.....	3.00	0.64	17	8	1	.....	410	26	0
" 8.....	2.99	0.66	15	8	1	900	160	42	0
" 9.....	3.00	0.67	14	8	1		Sunday.		0
" 10.....	2.99	0.67	11	8	1	850	450	18	0
" 11.....	3.00	0.66	10	7	1	1 000	600	26	0
" 12.....	3.01	0.64	8	6	1	750	350	16	0
" 13.....	3.00	0.62	9	5	1	700	120	10	0

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rates.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1908.									
Feb. 14.....	3.00	0.61	9	5	1	1 200	950	43	0
" 15.....	3.00	0.60	61	5	1	5 500	1 000	23	0
" 16.....	3.00	0.60	80	6	1		Sunday.		0
" 17.....	3.00	0.62	80	14	1	33 000	6 100	36	0
" 18.....	2.99	0.67	130	20	1	.....	2 000	11	0
" 19.....	2.99	0.76	320	18	2	28 000	9 000	120	0
" 20.....	2.99	0.83	177	15	2	22 000	8 500	190	0
" 29.....	3.00	0.85	123	8	1	.....	.....	.....	0
Mar. 1.....	3.00	0.87	97	9	1		Sunday.		0
" 2.....	2.99	0.92	82	13	1	8 000	4 400	50	0
" 3.....	2.98	0.96	87	19	1	11 000	2 100	26	0
" 4.....	2.99	1.02	67	21	1	6 000	4 700	7	0
" 5.....	2.99	1.08	59	25	1	4 400	10 000	36	0
" 6.....	2.99	1.15	72	25	2	7 000	7 400	50	0
" 7.....	2.98	1.21	82	25	2	9 500	6 500	28	0
" 8.....	2.99	1.26	92	29	2		Sunday.		0
" 9.....	2.99	1.30	125	34	2	11 000	4 800	25	0
" 10.....	2.99	1.35	142	39	2	8 500	1 200	23	0
" 11.....	2.99	1.39	155	35	2	6 500	2 400	20	0
" 12.....	2.99	1.42	135	29	2	5 900	1 500	11	0
" 13.....	2.99	1.46	122	19	2	1 900	1 100	12	0
" 14.....	2.99	1.47	97	12	1	1 800	700	6	0
" 15.....	2.99	1.48	77	8	1		Sunday.		0
" 16.....	3.00	1.52	65	6	0	1 400	700	8	0
" 17.....	2.99	1.66	59	7	0	900	800	11	0
" 18.....	2.99	1.72	67	11	1	1 000	650	8	0
" 19.....	2.99	1.75	60	24	1	.....	600	18	0
" 20.....	2.99	1.81	57	25	1	1 300	750	20	0
" 21.....	2.99	1.89	67	22	1	800	480	18	0
" 22.....	2.99	1.95	80	21	1		Sunday.		0
" 23.....	3.00	2.00	90	26	1	4 600	440	19	0
" 24.....	2.98	2.06	82	32	1	2 500	1 200	10	0
" 25.....	2.99	2.17	67	39	1	1 600	650	20	0
" 26.....	2.99	2.24	60	36	1	550	410	7	0
" 27.....	2.99	2.29	59	30	1	950	900	29	0
" 28.....	3.00	2.32	51	21	1	650	250	42	0
" 29.....	2.99	2.35	31	18	1		Sunday.		0
" 30.....	3.00	2.38	30	14	1	500	650	28	0
" 31.....	2.99	2.43	39	9	1	750	290	30	0
Apr. 1.....	2.99	2.50	44	7	1	750	390	32	0
" 2.....	2.99	2.58	42	8	1	1 100	280	47	0
" 3.....	2.99	2.65	41	11	1	1 500	550	70	0
" 4.....	2.99	2.74	54	12	1	700	380	4	0
" 5.....	3.00	2.82	50	12	1		Sunday.		0
" 6.....	2.99	2.88	41	14	1	440	150	4	0
" 7.....	2.99	2.98	35	13	1	650	270	42	0
" 8.....	2.98	3.15	39	11	1	550	210	65	0
" 9.....	2.99	3.35	40	8	1	390	160	95	0
" 10.....	2.98	3.50	40	8	1	500	130	130	0
" 11.....	2.99	3.65	45	7	0	430	145	100	0
" 12	2.99	3.79	52	5	0		Sunday.		0
" 13.....	2.99	3.92	50	4	0	490	160	80	0
" 14.....	2.99	4.05	45	4	0	550	170	90	0
" 15.....	2.99	4.16	45	3	0	420	160	12	0
" 16.....	....	4.24	45	3	0	380	130	90	0
" 21.....	Scraped, 0.12 in. of sand removed.								
" 23.....	....	0.13	25	2	0	140	140	.....	0
" 24	3.00	0.12	21	2	0	200	Lost.	150	0
" 25.....	3.00	0.10	20	2	0	85	550	45	0

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1908.									
Apr. 26.....	3.00	0.10	24	3	0		Sunday.		0
" 27.....	3.00	0.10	18	3	0	95	850	50	0
" 28.....	3.00	0.10	20	3	0	70	220	48	0
" 29.....	3.00	0.09	24	3	0	110	210	95	0
" 30.....	3.00	0.09	21	3	0	70	140	29	0
May 1.....	3.00	0.09	32	3	0	130	210	65	0
" 2.....	3.00	0.09	26	3	0	140	140	55	0
" 3.....	3.00	0.11	22	5	0		Sunday.		0
" 4.....	3.00	0.11	19	4	0	85	210	75	0
" 5.....	3.00	0.11	18	4	0	130	150	48	0
" 6.....	2.99	0.12	18	3	0	230	430	50	0
" 7.....	3.00	0.13	19	3	0	160	90	40	0
" 8.....	3.00	0.14	19	3	0	375	425	7	0
" 9.....	2.99	0.14	18	3	0	1 200	180	6	0
" 10.....	3.00	0.14	30	3	0		Sunday.		0
" 11.....	3.00	0.13	60	3	0	2 800	150	12	0
" 12.....	3.00	0.13	70	3	0	2 900	225	26	0
" 13.....	3.00	0.13	66	7	0	1 800	450	53	0
" 14.....	3.00	0.14	45	9	0	2 700	550	10	0
" 15.....	2.99	0.14	39	7	0	950	300	65	0
" 16.....	2.99	0.22	49	6	0	800	250	49	0
" 17.....	2.99	0.33	46	4	0		Sunday.		0
" 18.....	2.99	0.44	31	3	0	700	1 700	80	0
" 19.....	2.98	0.62	36	3	0	375	950	53	0
" 20.....	2.99	0.75	41	3	0	425	700	46	0
" 21.....	2.99	0.89	31	4	0	300	600	6	0
" 22.....	2.99	1.01	50	5	0	950	230	17	0
" 23.....	2.99	1.12	127	5	0	2 400	32	28	0
" 24.....	2.99	1.20	110	6	0		Sunday.		0
" 25.....	2.99	1.24	90	9	0	600	220	9	0
" 26.....	2.98	1.31	135	11	0	3 200	150	17	0
" 27.....	2.97	1.54	110	12	0	1 450	175	8	0
" 28.....	2.97	1.81	90	10	0	1 000	132	7	0
" 29.....	2.97	2.08	70	7	0	1 100	230	8	0
" 30.....	2.97	2.36	50	5	0		Holiday.		0
" 31.....	2.98	2.63	34	4	0		Sunday.		0
June 1.....	2.98	2.77	35	2	0	.....	.....	.....	0
" 2.....	2.98	2.84	39	2	0	.....	.....	.....	0
" 3.....	2.98	3.02	35	3	0	.....	.....	.....	0
" 4.....	3.00	3.01	30	4	0	.....	.....	.....	0
" 5.....	3.00	2.97	30	5	0	.....	.....	.....	0
" 6.....	3.01	2.81	27	5	0	.....	.....	.....	0
" 7.....	3.01	2.62	22	5	0	.....	.....	.....	0
" 8.....	3.01	2.38	20	4	0	.....	.....	.....	0
" 9.....	3.00	2.19	20	3	0	.....	.....	.....	0
" 10.....	3.01	2.02	17	3	0	.....	.....	.....	0
" 11.....	2.99	1.89	12	3	0	.....	.....	.....	0
" 12.....	2.98	1.92	11	2	0	.....	.....	.....	0
" 13.....	2.98	1.99	36	2	0	.....	.....	.....	0
" 14.....	2.98	2.08	39	2	0	.....	.....	.....	0
" 15.....	2.98	2.25	25	4	0	.....	.....	.....	0
" 16.....	2.98	2.54	34	5	0	.....	.....	.....	0
" 17.....	2.97	2.85	64	5	0	.....	.....	.....	0
" 18.....	2.97	3.20	57	5	0	.....	.....	.....	0
" 19.....	2.98	3.47	46	7	0	.....	.....	.....	0
" 20.....	2.98	3.73	37	8	0	.....	.....	.....	0
" 21.....	2.97	4.10	29	8	0	.....	.....	.....	0
" 22.....	2.97	4.44	25	6	0	.....	.....	.....	0
" 23.....	2.99	4.61	25	5	0	.....	.....	.....	

TABLE 19.—(*Continued.*)

Date.	Sand filter.		Turbidity.			Bacteria.			Coagulant.
	Rate.	Loss of head.	Applied water.	Effluent, coagulant.	Effluent, sand.	Applied water.	Effluent, coagulant.	Effluent, sand.	Grains, per gallon.
1908.									
June 26.....	3.01	0.09	15	2	0	.....	.....	.....	0
" 27.....	3.00	0.09	12	2	0	.....	.....	.....	0
" 28.....	3.00	0.09	9	2	0	.....	.....	.....	0
" 29.....	3.00	0.08	8	2	0	.....	.....	.....	0
" 30.....	3.00	0.07	10	2	0	.....	.....	.....	0
July 1.....	3.00	0.07	6	2	0	80	75	3	0
" 2.....	3.00	0.07	8	2	0	290	20	3	0
" 3.....	3.00	0.07	8	2	0	350	140	4	0
" 4.....	3.00	0.07	9	2	0		Holiday.		
" 5.....	3.00	0.07	10	2	0		Sunday.		
" 6.....	3.00	0.07	9	2	0	300	52	4	0
" 7.....	3.00	0.07	8	2	0	110	35	2	0
" 8.....	3.00	0.07	9	2	0	85	105	2	0
" 9.....	3.00	0.07	8	2	0	85	80	3	0
" 10.....	....	....	..	..	..	200	65	1	0
" 11.....	3.00	0.08	12	2	0	145	95	11	0
" 12.....	3.00	0.08	11	2	0		Sunday.		0
" 13.....	3.00	0.08	10	2	0	115	105	7	0
" 14.....	3.00	0.09	16	2	0	300	34	1	0
" 15.....	3.00	0.09	17	2	0	180	165	3	0
" 16.....	3.00	0.10	14	2	0	100	95	2	0
" 17.....	2.99	0.10	10	2	0	65	65	1	0
" 18.....	3.00	0.11	11	2	0	38	200	24	0
" 19.....	3.00	0.11	12	2	0		Sunday.		
" 20.....	3.00	0.12	10	2	0	95	31	1	0
" 21.....	3.00	0.12	10	2	0	70	100	2	0
" 22.....	3.00	0.13	13	2	0	450	13	4	0
" 23.....	2.99	0.13	54	2	0	650	325	4	0
" 24.....	2.99	0.14	305	2	0	1 650	325	..	0
" 25.....	3.00	0.15	330	4	0	2 600	55	2	0
" 26.....	3.00	0.15	290	9	0		Sunday.		
" 27.....	3.00	0.16	335	11	0	35 000	1 200	6	0
" 28.....	2.99	0.17	170	10	0	1 200	675	6	0
" 29.....	3.00	0.17	180	8	0	2 000	270	11	0
" 30.....	2.99	0.18	237	7	0	800	190	2	0
" 31.....	3.00	0.19	250	6	0	1 000	310	6	0

TABLE 20.—Summary of Results of Experimental Filters.

Filter number	1	2	3	4	5	6
Number of runs	3	6	11	12	25	28
Rate, million gallons per acre per day:						
Maximum	1.35	3.95	7.96	12.60	37.5	118.9
Minimum	0.62	2.30	3.73	5.77	6.68	7.1
Average	1.06	3.26	6.69	10.17	26.1	38.54
Length of run, in days:						
Maximum	233.5	150.5	75.2	90.9	48.71	39.83
Minimum	181.7	42.0	14.5	10.1	0.67	0.62
Average	206.4	109.6	48.89	40.5	14.41	12.61
Million gallons filtered per acre per run:						
Maximum	242.61	484.46	534.67	960.72	1 463.35	1 022.27
Minimum	202.60	135.66	93.79	92.57	19.53	53.32
Average	218.58	302.82	326.76	417.23	374.14	361.92
Cubic yards of sand removed per acre at end of each run:						
Maximum	269	269	672	1 612	2 420	3 360
Minimum	269	134	101	134	134	101
Average	269	213	272	392	583	635
Cubic yards of sand removed per acre per million gallons filtered	1.23	0.70	0.83	0.94	1.55	1.72
Average initial loss of head	0.07	0.19	0.51	0.78	3.88	5.38
Turbidity, influent:						
Maximum	120	120	120	120	90	100
Minimum	2	2	2	2	2	2
Average	20	20	21	22	18	19
Turbidity, effluent:						
Maximum	11	13	17	18	30	30
Minimum	0	0	0	0	0	0
Average	1	1	2	2	4	3
Percentage, reduction	95.0	95.0	90.5	90.9	77.8	84.3
Bacteria, influent:						
Maximum	180 000	180 000	180 000	110 000	180 000	37 500
Minimum	22	20	22	20	25	24
Average	4 800	5 100	4 500	4 200	6 900	5 900
Bacteria, effluent:						
Maximum	4 000	1 300	3 200	5 400	12 800	2 400
Minimum	2	3	1	1	2	2
Average	160	85	110	120	190	180
Percentage, reduction	96.7	98.3	97.6	97.3	97.3	97.0
Number of samples examined for *bacillus coli* in influent:						
10 c.c.	549	478	476	436	325	336
1 c.c.	560	492	486	445	335	342
0.1 c.c.	525	459	452	413	318	317
0.01 c.c.	511	443	439	405	308	304
0.001 c.c.	500	434	429	394	299	294
Number of samples examined for *bacillus coli* in effluent:						
10 c.c.	512	452	454	404	296	309
1 c.c.	513	454	457	406	299	311
0.1 c.c.	480	419	426	383	271	286
0.01 c.c.	478	406	410	367	261	276
0.001 c.c.	478	406	410	367	261	276

TABLE 20.—(*Continued.*)

Filter number	1	2	3	4	5	6
Number of runs	3	6	11	12	25	28
Number samples positive, influent:						
10 c.c.	226	211	201	258	136	152
1 c.c.	127	123	116	108	81	93
0.1 c.c.	55	59	54	51	43	42
0.01 c.c.	26	34	33	33	27	25
0.001 c.c.	6	6	5	6	3	3
Number samples positive, effluent:						
10 c.c.	100	109	134	98	94	106
1 c.c.	51	61	55	56	46	50
0.1 c.c.	9	13	16	16	4	13
0.01 c.c.	0	0	0	0	0	0
0.001 c.c.	0	0	0	0	0	0
Percentage of samples showing *bacillus coli* in influent:						
10 c.c.	41.2	44.2	42.2	59.2	41.9	45.2
1 c.c.	22.7	25.0	23.9	24.3	24.2	27.2
0.1 c.c.	10.5	12.8	11.9	12.3	13.5	13.2
0.01 c.c.	5.1	7.7	7.5	8.2	8.8	8.2
0.001 c.c.	1.2	1.4	1.2	1.5	1.0	1.0
Percentage of samples showing *bacillus coli* in effluent:						
10 c.c.	19.5	24.1	29.5	24.2	31.7	34.3
1 c.c.	10.0	13.4	12.0	13.8	15.4	16.1
0.1 c.c.	1.9	3.1	3.8	4.2	1.5	4.5
0.01 c.c.	0	0	0	0	0	0
0.001 c.c.	0	0	0	0	0	0
Cost per million gallons for sand handling	$0.43	$0.25	$0.29	$0.33	$0.54	$0.60
Interest charges at 3%	6.85	2.25	1.12	0.73	0.32	0.22
Total	7.28	2.50	1.41	1.06	0.86	0.82

Coli tests presumptive.

DISCUSSION

Mr. Hazen.

ALLEN HAZEN, M. AM. SOC. C. E. (by letter).—This paper contains a most interesting and instructive record of the actual operation of a large filter plant, and also a record of a number of experiments. The author has described some useful arrangements for improving the efficiency or reducing the cost.

The utility of raking, as an intermediate treatment between scrapings, seems to have been clearly demonstrated. Its practical effect is to allow a greater quantity of water to be passed between scrapings, thereby saturating—if the term may be used—the surface layer with clay and other fine matter before removing it, instead of taking it off when only a thin surface layer of it has been thus saturated.

The large proportion of the total purification that takes place in passing through three reservoirs successively, holding in the aggregate a quantity of water equal to about 7 days' use, is very striking. Taking all the records, the percentage remaining after passing through these reservoirs, is as follows:

Sediment for the year, 1909-1910, Table 2	17%
Turbidities, 5-year average, Table 3	25%
Bacteria, 5-year average, Table 4	24%
Bacteria, selected winter months with high numbers in the raw water	20%
Bacteria, selected summer months with high numbers in the raw water	2.5%

There is considerable seasonal fluctuation in the results of settling and filtering, as is shown in Table 21.

TABLE 21.—AVERAGE REMOVAL OF TURBIDITY AND BACTERIA BY WASHINGTON FILTERS FOR WHOLE PERIOD, ARRANGED BY SEASONS.

		Winter.	Spring.	Summer.	Fall.	Year.
Turbidity, in parts per million:	raw	136	96	144	42	105
	settled	33	28	27	15	26
	filtered	4	3	1	0.5	2
Percentage left from:	settling	24	29	19	36	25
	filtering	12	10	4	3	8
	both	3	1	0.3	1	2
Bacteria per cubic centimeter:	raw	16 600	4 150	4 100	1 960	6 700
	settled	6 300	980	160	270	1 940
	filtered	149	29	18	22	54
Percentage left from:	settling	38	24	4	14	29
	filtering	2.4	3.0	11.2	8.2	2.8
	both	0.90	0.70	0.44	1.12	0.81

The fluctuation in the efficiency of the plant as a whole by seasons is greater with the turbidity than with the bacteria. During the winter

the effluent contains 3% of the turbidity of the raw water, and in summer only 0.3 per cent. Most of this difference is represented by the increased efficiency of the filters in summer, and only a little of it by the increased efficiency of settling. With bacteria, on the other hand, the seasonal fluctuation of the plant as a whole is comparatively small, but the settling and storage processes are much more efficient in summer than in winter, the filters being apparently less efficient. The writer believes that they are only apparently less efficient, and not really so, the explanation being that some bacteria always grow in the under-drains and lower parts of the filter, and are washed away by the effluent. The average number of bacteria in summer in the settled water is 160 per cu. cm. and in the filtered water 18. These are very low numbers. It is the writer's view that nearly all of these 18 represent under-drain bacteria, and practically bear no relation to those in the applied water, and, if this view is correct, the number of bacteria actually passing through the various processes is at all times less than the figures indicate. In the warmer part of the year the difference is a wide one, and the hygienic efficiency of the process is much greater than is indicated by the gross numbers of bacteria. Mr. Hazen.

The reduction of the typhoid death rate has not been as great with the change in water supply as was the case at Lawrence, Albany, and other cities, apparently because the Potomac water before it was filtered was not the cause of a large part of the typhoid fever.

The sewage pollution of the Potomac is much less than that of the Merrimac and the Hudson, and it is perhaps not surprising that this relatively small amount of pollution was less potent in causing typhoid fever than the greater pollution of rivers draining more densely populated areas.

The method of replacing the washed sand hydraulically seems to have worked better than could have been reasonably anticipated, and the writer believes that this was due, in part, to the excellent method of manipulation described in the paper. It is his feeling, however, that part of the success is attributable to the very low uniformity coefficient of the sand. In other words, the sand grains are nearly all of the same size, due to the character of the stock from which the filter sand was prepared; and, therefore, there is much less opportunity for separation of the sand according to grain sizes than there would be with the filter sand which has been available in most other cases.

Filter sand with a uniformity coefficient as low as that obtained at Washington has been rarely available for the construction of sand filters, and while the method of hydraulic return should certainly be considered, it will not be safe to assume that equally favorable results may be obtained with it with sands of high uniformity coefficients until actual favorable experience is obtained.

The writer believes that in calculating the cost of the water used

Mr. Hazen.

in the plant itself the price chosen by the author, covering only the actual operating expenses of pumping and filtering, is too low. The capacity of the whole Washington Aqueduct system is reduced by whatever quantity is used in this way, and, in calculating the cost of sand handling, the value of the water used should be calculated on a basis which will cover the whole cost of the water, including all capital charges, depreciation, operating expenses, and all costs of every description. On this basis the water used in the sand-handling operations would probably be worth five or more times the sum mentioned by the author.

The cost of operation of the plant has come within the estimates made in advance, and has certainly been most reasonable. The cost of filter operations has averaged only about 50 cents per million gallons, and is so low that it is obvious that the savings which may be made by introducing further labor-saving appliances would be relatively small. It will be remembered that ten or fifteen years ago the cost of operating such filters under American conditions was commonly from $2 to $5 per million gallons.

The experiments represented by Tables 17 to 19, inclusive, serve to show that preliminary filtration, or multiple filtration, or any system of mechanical separation is incapable of entirely removing the finer clay particles which cause the residual turbidity in the effluent. They also show that this turbidity may be easily and certainly removed by the application of coagulant to the raw water during the occasional periods when its character is such as to require it.

These general propositions were understood by those responsible for the original design of the plant, as is shown by the author's quotations. These experiments, however, were necessary in order to demonstrate and bring home the conditions to those who thought differently, and who believed that full purification could be obtained by filtration alone, or by double filtration, without recourse to the occasional use of coagulant.

The experiments briefly summarized in Table 20 are of the greatest interest and importance. Six small filters, otherwise alike and like the large filters, all received the same raw water and were operated at different rates to determine the effect of rate on efficiency.

That the experimental results from the filter operating at the same rate as the large filters were on the whole somewhat inferior to those from the large filters for approximately the same period, may be attributed to the fact that the experimental filter was new while the large filters had been in service for some time and had thereby gained in efficiency. The greatest difference was in the *coli* results in Table 20, where it is shown that 24% of the 10-cu. cm. effluent samples from the experimental filter contained *coli*, in comparison with only from 1 to 3% of such samples from the main filters.

Mr. Hazen.

The results from the experimental filter operating at a rate of 1 000 000 gal. per acre daily may fairly be excluded, as the effluent probably contained more under-drain bacteria in proportion than filters operated at higher rates. The number of bacteria in the filter operating at a 3 000 000-gal. rate were 1.7% of those in the applied water; for the filter operating twice as fast, the percentage was 2.4; and, for the one operating more than ten times as fast, was only 3.0; thus indicating a surprisingly small increase in the number of bacteria with increase in rate.

Further and more detailed study by the writer of the unpublished individual results, briefly summarized in Table 20, confirms the substantial accuracy of the comparison based on the average figures as stated in that table.

It must be kept in mind, in considering these results, that the number of bacteria in each case is made up of two parts, namely, those coming through the filter—which number is presumably greater as the rate is greater—and, second, those coming from harmless growths in the under-drains and lower parts of the filter—the numbers of which per cubic centimeter are presumably less as the rate is greater—and these two parts, varying in opposite directions, may balance each other, as they seem to do in this case, through a considerable range. It may thus be that the number of bacteria really passing the filter varies much more with the rate than is indicated by the gross results.

It is also of interest to note that the sand filter (called a preliminary filter) in Table 18, filled with the same kind of sand, when operated at an average rate of 50 000 000 gal. per acre daily for a year, allowed 18% of the applied bacteria to pass, in comparison with 3% found in Filter No. 6 of Table 20, operated at an average rate of 38 000 000 gal. per acre daily.

There was one point of difference in the manipulation: the preliminary filter was washed by a reversed current of water, as mechanical filters are washed, while Filter No. 6 was cleaned by scraping off the surface layer, as is usual with sand filters. Whether the great difference in bacterial results with a relatively small difference in rate is to be attributed to this difference in manipulation the writer will not undertake to state.

If the experimental results of Table 20 indicate correctly the conditions which obtain in filtering Potomac water, then increasing the rate of filtration so as to double it, or more than double it, would make but little difference in the quality of the effluent as measured by the usual bacterial methods. If the increase in rate were accompanied by the preliminary filtration of the water, then, presumably, there would be little change in the quality of the effluent, and the maintenance of excellent results might be incorrectly attributed to the influence of the preliminary filter.

Mr. Hazen.

It would also seem that the apparatus which is sometimes used for determining and controlling the rate with more than the ordinary degree of precision is hardly justified by such experimental results as those presented by the author.

In contrast to these results may be mentioned those obtained by Mr. H. W. Clark,* for experimental filters operated with Merrimac River water, at rates ranging from 3 000 000 to 16 000 000 gal. per acre daily. The results are the average of nearly two years of experimental work, the period having been nearly coincident with that covered by the author's experiments, and of many hundreds of bacterial analyses of each effluent, and form, with the author's experiments, the most thorough-going studies of the effect of rate on efficiency that have come to the writer's attention.

Mr. Clark's results are given in Table 22.

TABLE 22.

Effective size of sand.	Filter No.	Rate, in gallons per acre daily.	Bacteria per cubic centimeter in effluent.	Bacterial efficiency.	*B. Coli* in 1 cu. cm. (percentage of positive tests).
0.28	A	3 000 000	48	99.1	5.0
0.25	B	5 000 000	85	98.4	24.0
0.22	C	7 500 000	105	98.1	25.0
0.22	D	10 000 000	110	98.0	25.0
0.22	E	16 000 000	280	95.0	38.0

It will be seen that the number of bacteria passing increases rapidly with the rate, and whether the total number of bacteria is considered or the *B. coli* results, the number passing is approximately in proportion to the rate. In other words, doubling the rate substantially doubles the number of bacteria in the effluent.

This is entirely in harmony with all the Lawrence experimental results extending over a period of 20 years. There have been occasional apparent exceptions, but, on the whole, experience with Merrimac River water has uniformly been that more bacteria pass as the rates are higher.

The theory sometimes advanced, that the efficiency of filtration is controlled to a certain extent by gelatinous films, and that, as far as thus controlled, is less dependent on rate, would not seem to be borne out by these results. The Merrimac River water, carrying large amounts of organic matter, would certainly seem better adapted to the formation of such films than the clay-bearing Potomac water, comparatively free from organic matter; but it is the Potomac water which seems to show the least influence of rate on efficiency.

* *Journal*, New England Water-Works Association, Vol. 24, p. 589.

Mr. Hazen.

The experiments show that turbidity passes more freely at the higher rates with the Potomac water, as has also been found to be the case with other clay-bearing waters.

In the last lines of Table 20 are given cost per million gallons for filtering at various rates. There is no discussion of these figures, and as they differ considerably from those which the writer has been accustomed to use, the calculation in Table 23, made three years ago for a particular case, may be of interest.

TABLE 23.—RELATIVE COST OF FILTERING AT DIFFERENT RATES.

	Nominal rate, in millions of gallons per acre daily:			
	3	5	10	20
Percentage which average yield is of nominal rate	85	80	75	65
Average output per acre, in millions of gallons per day	2.55	4.00	7.5	13.0
Cost of that part of filters per acre dependent on rate	$12 000	$20 000	$40 000	$80 000
Cost of that part of filters per acre not dependent on rate	50 000	50 000	50 000	50 000
Total cost of filters per acre	60 000	70 000	90 000	130 000
Cost per million gallons of capacity	20 600	14 000	9 000	6 500
Cost per million gallons of average daily output	24 400	17 500	12 000	10 000
Capital charges and depreciation at 6% on cost per million gallons	4.00	2.87	1.97	1.64
Operating expenses, the same at all rates	1.00	1.00	1.00	1.00
Total cost of filtering, excluding pumping, storage, and all auxiliaries	5.00	3.87	2.97	2.64
Relative cost	1.29	1.00	0.77	0.68

When the costs of pumping, pure-water reservoirs usually necessary, etc., are taken into account (which add equally to the cost at all rates), the cost of filtering will vary less with the rate than is indicated.

The effect of rate on cost, as calculated in Table 23, and also the percentages of the bacteria of the raw water found in the effluents by the author and by Mr. Clark, are shown on Fig. 10.

Considering all these results together, and also all the other evidence known to the writer bearing on this point, it seems clear that filters are not as sensitive to changes in rate, within reasonable limits, as has been frequently assumed; but, on the other hand, there is usually a substantial increase in the percentage of bacteria passing through a filter with increased rate.

Filters furnish relative, not absolute, protection against infectious matter in the raw water. The higher the bacterial efficiency, the more complete is this relative protection.

The cost of filtering does not decrease in inverse ratio to the rate, but at a much slower rate. This is especially true with rates of more than 5 000 000 or 6 000 000 gal. per acre daily.

Mr. Hazen.

In general, a rate of filtration may rationally be selected at which the value of the possible danger resulting from an increase in rate is equal to the saving that may be made in cost by its use. This point must be a matter of individual judgment. The tendency of the last few years has been to use higher rates, or, in other words, to cheapen the process and to tolerate a larger proportion of bacteria in the effluent. The use of auxiliary processes has been favorable to this, especially

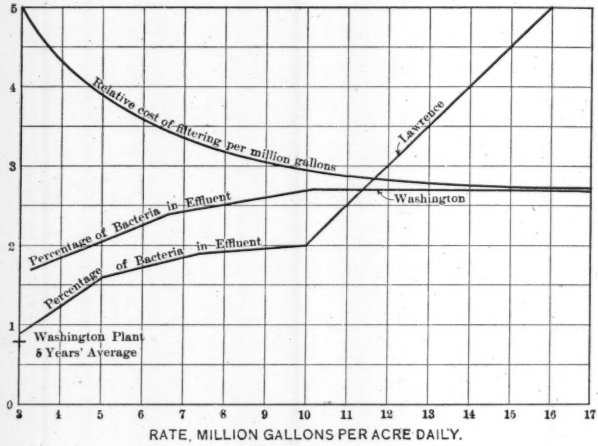


FIG. 10.

the use of chloride of lime, in connection with either the raw water or the effluent.

By the judicious use of this substance, efficiency may be maintained while using higher rates than would otherwise have been desirable.

The writer believes that there will be many cases where the added risk of using too high a rate is not worth the relatively small saving in cost that accompanies it.

Mr. Johnson.

GEORGE A. JOHNSON, ASSOC. M. AM. SOC. C. E.—This paper contains information of an exceedingly interesting nature. There is comparatively little difficulty in obtaining accurate figures on the cost of construction of water purification works, but, with costs of operation of such works, it is different. The data available in published reports and papers are usually more or less fragmentary, and unexplained local conditions with reference to the character of the raw water, the cost of labor and supplies, and methods of apportioning these costs, introduce variables so wide as frequently to render the published figures almost useless for purposes of comparison.

Mr. Johnson.

Mr. Hardy's paper is noteworthy in that it presents certain relatively new features of slow sand filter operation which have been only lightly touched on in water purification literature up to the present time. These refer particularly to means whereby a filter may be continued in service without removing a portion of the surface layer of the filter surface itself when the available head has become exhausted, and to methods whereby washed sand may be expeditiously and more economically restored to the filter than has been the case hitherto.

Sand handling is the most important item of expense in the operation of a slow sand filter. Quite recently a charge of $1.50 per cu. yd. for sand scraping, transportation to sand washers, washing, and restoring to the filter, was not considered exorbitant, but the improved methods developed during recent years at Washington, Philadelphia, Albany, and more recently at Pittsburg (at all of which places hydraulic ejection plays an important part), have shown the feasibility of reducing this figure by nearly, if not quite, two-thirds.

The practice observed at Washington of raking over the surface of the sand layer when the available head becomes exhausted, in order to avoid the cost and loss of time necessitated by shutting down the filter and scraping off the surface layer, is unquestionably one of the most striking advances in slow sand filter operation in recent years. In rapid sand filter operation, to prolong the period of service between washings, agitation of the filter surface has been used to advantage for many years. The full value of surface raking may not be generally appreciated, but the results which have followed a trial of this procedure at Washington, Philadelphia, and Pittsburg have shown that the output of filtered water between scrapings may be doubled or trebled thereby, with no injury to the filter itself or to the quality of the filtered water. The cost of raking over the surface of a 1-acre slow sand filter unit is less than $10 at all the above-mentioned places, which fact in itself shows the great saving in money and time effected by periodically substituting surface raking for scraping. Under ordinary conditions it has been found that a filter can be raked to advantage at least twice between scrapings.

In the case of filters thus raked, a deeper penetration of suspended matter into the sand layer is inevitable, but at Pittsburg, as at Washington, such penetration does not extend more than about 2 in. below the filter surface. When the filter is finally scraped, a deeper layer is removed, of course, but it is clearly more economical to remove a deep layer at one operation than to remove separately several thinner layers of an equal total thickness.

The lost-time element is an important one, and at Washington this was the main reason for trying surface raking. It became necessary to increase the output of the filters, and the ordinary scraping consumed so much time that the sand-handling force was increased, working day

Mr. Johnson.

and night. The raking expedient introduced at this time overcame this, and Mr. Hardy states that it is still followed when the work is at all pressing. The speaker has found at Pittsburg, as Mr. Hardy has found at Washington, that raking is nearly if not quite as effective as scraping in restoring the filter capacity.

Eleven years ago the speaker was connected with the preliminary investigations into the best methods of purifying the Potomac River water for Washington. It then appeared that while for the greater part of the time during an average year the Potomac River could be classed among the clear waters of the East, there were periods when excessive turbidity made it necessary to consider carefully methods of preparatory treatment before this water could be filtered effectively and economically. As Mr. Hardy has said, considerable prejudice existed against the use of a coagulating chemical, and the expedient was therefore adopted of giving the water a long period of sedimentation in order to remove enough of the suspended matter to allow the clarified water to be treated on slow sand filters. The expert commission, consisting of Messrs. Hering, Fuller, and Hazen, recommended the occasional use of a coagulating chemical, but this recommendation was not carried out.

The Potomac River is somewhat peculiar, in that the turbidity of its waters, as shown by the results presented in Mr. Hardy's paper, ranges from 3 000 to practically nothing. The bacterial content also varies widely, and Mr. Hardy's tables show this variation to be from 76 000 to 325 per cu. cm. Such a water as this requires particularly careful preparatory treatment. The Dalecarlia Reservoir has a capacity of something like 2 days' storage, the Georgetown Reservoir the same, and the McMillan Park Reservoir nearly 3 days, making a total sedimentation of more than 7 days. Without the use of a coagulant, it is significant that during a period of five years, even with 7 days' sedimentation, the average maximum turbidity of the water delivered to the filters was 106 parts per million, and the maximum average turbidity in one month was 250 parts per million. The water filtration engineer can readily understand that waters as turbid as this cannot be treated economically and efficiently in slow sand filters. It would appear that coagulating works might advantageously have been installed at the entrance to the Dalecarlia Reservoir. If this had been done, and coagulant had been added to the water at times when it was excessively turbid, a considerably shorter period of subsequent sedimentation than now exists would in all probability have rendered the water at all times amenable to efficient and economical slow sand filter treatment.

The prejudice in Washington against the use of coagulants has also manifested itself in other localities, but the results which have been obtained during the past twenty years from rapid sand filters and from slow sand filters, treating waters previously coagulated with salts of iron or alumina, have shown how thoroughly unreasonable were these

objections. In this connection it is interesting to note that there are in the United States more than 350 rapid sand filter plants, and that nearly 12% of the urban population of Continental United States is being supplied with water filtered through rapid sand filters, in connection with all of which a coagulating chemical is used in the preparatory treatment. Mr. Johnson.

TABLE 24.—TYPHOID FEVER DEATH RATES IN CITIES OF THE UNITED STATES WITH POPULATIONS IN 1910 OF 100 000, OR MORE.

Statistics gathered by correspondence and from Reports of the Bureau of the Census, Department of Commerce and Labor, Mortality Statistics.

NOTE.—Statistics from Birmingham, Ala., Dayton, Ohio, Fall River, Mass., Louisville, Ky., Memphis, Tenn., Oakland, Cal., and Providence, R. I., are not included, as they are incomplete.

City.	TYPHOID FEVER DEATH RATE PER 100 000 POPULATION.							
	1906.	1907.	1908.	1909.	1910.	Average for six years, 1900–05, inclusive.	Average for five years, 1906–10, inclusive.	Average for 11 years, 1900–10, inclusive.
Albany, N. Y.	20	20	11	19	15	25	17	21
Atlanta, Ga.	50	64	47	44	43	65	50	58
Baltimore, Md.	34	41	31	23	41	36	34	35
Boston, Mass.	22	10	26	14	11	23	16	20
Bridgeport, Conn.	10	13	13	13	9	15	12	14
Buffalo, N. Y.	24	29	21	23	20	29	23	26
Cambridge, Mass.	18	10	10	9	12	18	12	15
Chicago, Ill.	18	18	15	12	14	27	16	22
Cincinnati, Ohio.	71	46	19	18	6	54	31	44
Cleveland, Ohio.	20	19	13	12	19	51	17	36
Columbus, Ohio.	45	38	110	17	13	61	45	54
Denver, Colo.	68	67	58	24	30	37	49	42
Detroit, Mich.	22	28	22	19	16	17	22	19
Grand Rapids, Mich.	39	30	30	17	27	34	28	31
Indianapolis, Ind.	39	29	26	22	31	76	30	55
Jersey City, N. J.	20	14	10	8	10	19	12	16
Kansas City, Mo.	38	40	35	23	38	48	35	42
Los Angeles, Cal.	18	23	19	18	12	35	18	27
Lowell, Mass.	7	9	24	11	21	19	14	17
Milwaukee, Wis.	31	26	17	21	45	19	28	23
Minneapolis, Minn.	33	26	18	20	58	38	29	34
Nashville, Tenn.	66	85	62	53	48	54	58	56
Newark, N. J.	18	24	12	11	18	17	16	17
New Haven, Conn.	54	30	34	20	17	44	31	38
New York, N. Y.	15	17	12	12	12	19	14	17
New Orleans, La.	30	56	31	25	28	40	34	37
Omaha, Nebr.	28	24	22	31	75	20	36	27
Paterson, N. J.	4	11	10	5	7	25	7	17
Philadelphia, Pa.	74	60	36	22	17	47	42	45
Pittsburg, Pa.	141	135	53*	13*	12*	132	71	104
Richmond, Va.	44	41	50	24	22	66	36	53
Rochester, N. Y.	17	16	12	9	13	15	13	14
St. Louis, Mo.	18	16	15	15	14	33	16	25
St. Paul, Minn.	21	17	12	20	20	14	18	16
San Francisco, Cal.	..	57	27	17	15	20	29	24 (?)
Scranton, Pa.	11	76	11	11	14	18	35	26
Syracuse, N. Y.	10	16	15	12	30	14	17	15
Toledo, Ohio.	45	36	40	31	32	36	37	36
Worcester, Mass.	12	14	10	8	16	17	12	15
Washington, D. C.	52	36	39	33	23	59	37	49

* Filtered water section. Allegheny District not included.

Mr. Johnson.

Attention has repeatedly been called to the fact that the relatively high typhoid death rate in Washington, since the filter plant was installed, was a possible indication that the filters were inefficient. It is true that there has not been the marked reduction in the typhoid death rate in Washington, following the installation of the water filtration works, that has been observed in other cities in America. For the six years prior to the date on which filtered water was supplied to the citizens of Washington, the average typhoid fever death rate was 59 per 100 000 population, as against 37 per 100 000 for the five years following, a reduction of 37 per cent. At Albany, N. Y., where the first modern slow sand filter was built in 1899, the typhoid death rate has been reduced by 75 per cent. At Cincinnati, Ohio, the average death rate from typhoid ranged around 50 per 100 000 for years, but since the installation of the filtration plant it has been reduced to a point which places that city, with respect to freedom from typhoid fever, at the head of all the large cities in America; in 1910 the death rate from typhoid in Cincinnati was 6 per 100 000. Similarly, at Columbus, Ohio, where the typhoid death rate before the installation of the filtration plant in 1906 was even higher than at Cincinnati, it was reduced to less than 13 per 100 000 in 1910, whereas, for the previous five years, it was 61 per 100 000. Philadelphia, before the installation of the filtration works, had a typhoid death rate of 60 or more per 100 000, and in 1910 the death rate from this disease was 17. Pittsburg, at least that part of it now supplied with filtered water, for years had a typhoid death rate of more than 130 per 100 000, but the present rate is about 12 per 100 000.

TABLE 25.—AVERAGE MONTHLY RESULTS FOR THE PERIOD, 1905-1910.

Reservoirs.	Period of sedimentation, in days.	Turbidity, in parts per million.	Bacteria per cubic centimeter.	Percentage Removed.	
				Turbidity.	Bacteria.
River	....	106	6 400	..	..
Dalecarlia	2.2	50	5 000	53	22
Georgetown	2.2	38	3 400	24	32
McMillan	2.8	26	2 000	81	41
Totals and averages	7.2	....	.....	75	69

While it may perhaps seem unreasonable to single out Washington as a particular sufferer in this respect, it is highly probable that a large share of the typhoid is still caused by secondary infection, flies, impure milk, and private and public wells. The speaker remembers distinctly that ten years ago, when he made an investigation into the purity of the water of about 100 public wells in that city, a large num-

ber of them showed unmistakable evidence of being polluted with sewagic matter. Conclusive evidence would be secured to dispel any doubt as to the sanitary quality of the filtered product if hypochlorite of lime were added to the filtered water throughout one year or throughout the typhoid months. It seems strange to the speaker, that for this, if for no other reason, this safe and non-injurious germicide has not as yet been used at Washington, in view of the fact that at the present time it is being used continuously or intermittently in the treatment of the water supplies of scores of the most important cities of this country, among which may be mentioned New York, Philadelphia, Cincinnati, Pittsburg, St. Louis, and Minneapolis. Mr. Johnson.

MORRIS KNOWLES, M. AM. SOC. C. E. (by letter).—This description of the operation of the Washington Filtration Works is timely and of great interest. It is ten years since the writer, in collaboration with Charles Gilman Hyde, M. Am. Soc. C. E., presented a similar record for the Lawrence, Mass., filter. That paper was the first complete, detailed, and continuous history of the actions and results obtained for a long period of time with such a purification works.* Since then, the art of filtration has advanced in many ways, particularly in regard to the methods of cleaning slow sand filters and in the accompanying processes. It is well, therefore, again to take account of stock and see really what progress has been made. Therefore, Mr. Hardy's paper, giving a description of the operations of a system thoughtfully designed, after long consideration of the problem, and of operations carried on under efficient and economical administration, with thorough record of all details, should furnish a groundwork for the careful consideration of the question stated above. Mr. Knowles.

The writer, using as a text some of the ideas given in the paper, but more particularly some of those becoming prevalent elsewhere, desires to discuss methods and costs of operation, especially in relation to sand handling; and to offer suggestions looking toward greater efficiency, as well as economy, in carrying out the standard and well-tried methods.

Theory of Slow Sand Filtration.—First, what is the process of slow sand filtration? The answer to this question involves many factors, some of which are even yet but imperfectly understood. In the early history of filtration, at the time of the construction of the London filters, only the straining capacity of the sand bed, to remove gross particles, was known. Later, when the organic contents of water had become better understood, the chemical or oxidizing powers of the process were recognized as performing an important part. Finally, co-existent with the discovery of the so-called "germ theory of disease," a study of the bacterial action of filters resulted in the recognition

* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 258.

Mr. Knowles.

of its importance. It is now universally thought that each of these factors performs its useful function; that the size of the sand, the amount of organic matter remaining on the surface of the bed, the turbidity of the applied water, and the bacterial content of the influent, are some of the things on which depends the determination of the relative importance of each.

Engineers have been taught to believe, by the German school of thought, that the film of organic matter on the surface of the sand plays a very important rôle in filtration. This *Schmutzdecke,* as it is called, has been considered so precious that stress has been placed on treating it with great care. It was not to be wholly removed at the time of cleaning, and it was not to be walked on, or indented, or in any other way consolidated or destroyed. In fact, in some cases, the wasting of the first water after cleaning has been advocated, for the reason that not a sufficient amount of this organic film would be left on top of the sand to begin the filtration process properly immediately after the cleaning.

In late years, however, there has been a tendency to depart from this fundamental doctrine of slow sand filtration. Various new processes for cleaning the sand surface have been advocated; some of these partly destroy and others completely exterminate any semblance of a bacterial film on the sand bed. These ideas, advanced without any real and serious discussion of their intrinsic merits, or their effects on the public health, are not founded on long continuous records of such results as are necessary to establish confidence in the final value of any of these methods.

Rapid advances along this line have been made more recently, notwithstanding the occurrence of notable instances of trouble and the resultant need of complete repair of filtration beds. Because of the rough treatment of the sand surface, a penetration of organic matter and filth into the bed had taken place. This caused deep clogging, prevented the usual yield of water, and brought about a lessened bacterial efficiency, due to the attempt to force water through the filters, and because some organic matter and growths in the lower part of the bed had furnished a breeding place for more bacteria.

All these endeavors to reduce the work of cleaning have been commendable, because scraping and sand handling are the items of greatest expense in slow sand filter maintenance. Every one has been desirous of minimizing this cost. However, as the writer will endeavor to show, it seems that attempts along this line should be with the idea of doing more economically, as well as efficiently, the things which one knows will accomplish the proper results, rather than unwisely to adopt new methods which have not been tried for a long enough period to determine their effect on the public health.

Pittsburg Methods.—When first taking up the problem of design

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in Pittsburg, in 1902, the writer had presented to him for consideration and adoption, a suggestion that a certain method of cleaning sand filters, which would involve the washing of the sand in place (similar to that recently tried at the Jerome Park Experiment Station, New York City), would be advisable and economical. The decision then made has never been regretted. As this plan involved such a complete departure from those principles which had been well tried and had proven successful, it was believed that it was not safe to adopt such a method on the municipal filtration works, from which the people were to derive their drinking water. There is more to be considered in such a problem than mere economy of operation; the economy of human life, the effect on which requires far longer than a few months of trial to determine, is a much more important factor. Believing that no one should depart, until after a long period of conclusive experimentation, from that principle which is known to be safe (viz., to take off a small portion of the clogging surface), the writer studied to determine more efficient and economical methods of accomplishing this end.

A device for scraping the material, in just the same way as with shovels, but more efficiently and more exactly, was developed by George P. Baldwin, M. Am. Soc. C. E., under the general supervision of the Bureau of Filtration, of which the writer was in charge. However, on account of the unfortunate and earlier arrangement of other constructive matters, which the City's Legal Department advised could not be changed without upsetting the contract, the entrance doors to the original forty-six filters were not built large enough to permit the rapid and economical transfer of these machines, and, as this act takes so large a proportion of the total time of operation, it has not been found economical to use them. The additional ten filters, recently constructed, with doors especially designed and large enough to pass the machines, have not yet been placed in operation. This is said to be on account of lack of funds and of employees. Therefore, there has been no opportunity to demonstrate what the scraping machines can do, under the conditions for which they were designed to operate. The restoring machine, a complementary device in mechanical operation, which simply replaces the sand in the same condition that it would be if wheeled back, but, with a small percentage of moisture, has accomplished its purpose well and economically. The sand is placed in the filters so that there is no further settling; with a smooth surface, needing no additional adjustment; with absolutely no possibility of sub-surface clogging; and with the filters starting off exceedingly well in operative results.

Washington Methods.—In Washington, it is stated that the filters are still cleaned by the old-fashioned method of scraping with shovels, throwing the sand into piles, and afterward removing it with a

Mr. Knowles.

movable ejector. Between scrapings there is also an occasional mid-period action of raking the unwatered sand surface, for the purpose of stirring up the dirty film. This process does not remove any of the clogging material from the bed, but it is said that no injurious effects are produced, and that it is economical. It is stated that the so-called "Brooklyn method," of stirring the surface of the sand while the water is on the bed, has been tried at Washington, but with unsatisfactory results. It seems to have been advocated with greater fervor in some other places.

The method of dry raking does not remove the dirty material, but loosens up the pores of the surface, and through this porosity permits clogging to penetrate deeper into the filter. The method of raking with water on the bed, although it removes some of the organic dirt, also permits deeper penetration of the remainder. The latest devised system of washing the sand in place, by upward spraying with water, called the "Blaisdell method," thoroughly destroys the *Schmutzdecke* above, and, at the same time, must permit the formation of a subsidiary one below. In the Nichols method, the material removed by shovel scraping is conveyed by an ejector to a portable separator, where it receives a single washing; the dirty water overflows to the sewer, while the washed sand is discharged through a hose and deposited on the recently scraped surface. As the latter is partly impregnated with impurities, there is, by this process, a tendency toward sub-surface clogging.

All these processes are marked and serious departures from the well-tried method of cleaning slow sand filters, which, it is well known, will operate successfully to purify polluted river waters and make them safe to drink. In all there is the danger that they have not been sufficiently and carefully tried, under scientific observation, as to results and possible effects on the public health, to be sure that the bacterial efficiency can long continue to be satisfactory, with the application of specifically infected waters. It is dangerous, and may even jeopardize the safety of human lives, to experiment on water which is furnished for drinking purposes. There is also the added danger, well known from past experience, that in a few years (it may be more or less, depending on the extent and intensity of the new workings) the filters will need renovation, partly, if not wholly, throughout the entire bed. Thus, considering the total cost during a long term of years, the apparently cheaper method may become the most expensive.

There is also an interesting query in regard to the Washington method of replacing sand in the filters, and it is worthy of most careful thought and attention. If the process described can be carried on with success and safety, it will prove to be a long and progressive step in the methods of operation. The difficulty, however, is in determining from any short-term runs whether such a process can be continued permanently without impairing the efficiency of the sand

bed. Apparently good conditions may change, after a few years' trial, and be followed by unsafe results and predicaments. This replacing of sand with whatever dirt and detritus may travel with it in the carrying water is certainly not equivalent to the care with which it has been understood that sand should be deposited in filters. It is not comparable with the care with which it is placed, when wheeled from a washer, where dirty water overflows the lip, or where it is placed by a machine restorer in the filter, where the transporting water also overflows the weir and is carried to the sewer. Mr. Knowles.

These cheap and rapid methods of doing the work, advanced in the interests of economy, and the idea that sand filters, receiving polluting waters, can operate at higher rates than those which we have demonstrated, and, therefore, have been led to believe are safe, is a speeding up of the whole organization and of operating conditions. It is like speeding up a machine for the purpose of getting a greater output, with the usual result that fast running means quicker wearing out of both man and machine. Quicker operations generally mean carelessness in doing the work, especially in municipal service. Carelessness is engendered by the thought that such work can be handled in a rough and rapid way, and, further, by the ridicule of all these things, which we have learned to be careful about, as old-fogyish, out-of-fashion, and archaic. Carelessness in operation breeds contempt for the art. Some of the less efficient filter plants, from the standpoint of effect on the public health, may reflect such ill-considered methods.

Economy with Efficiency in Operation.—It is particularly important to find out whether one can secure the desired economy, and, at the same time, the required efficiency. The development of efficiency in every line of human endeavor is receiving much attention at present, and not the least cause for this is the growing recognition of the demand for a high standard of service for the expense caused. One of the first requirements is to have well-defined ideals and standards. When one knows how to secure a good and safe result, it is unwise to depart therefrom for a mere whim, or to secure a supposedly lessened expense, unless other facts be also determined favorably. The desire for economy must be tempered by good sense, which means that one should be willing to change a method only when the wisdom of such has been clearly demonstrated. Efficient service can only be secured by strict discipline, accompanied by fair dealing. This means employing no more men than are actually necessary, paying them on the basis of the standard of service and output produced, taking an interest in the working conditions, and providing for their health and welfare.

About twelve years ago, the writer made some investigations of the efficiency of laboring gangs in scraping and handling sand at filter beds,* and found that ten men was the most economical number to

* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 291.

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use in scraping the surface of the Lawrence filter, as then built and operated. This result was determined by numerous studies of the output per man per minute, with different numbers of men working under different conditions. This same sort of study has been carried further by adepts in the art, in reference to shop and similar management, but one fails to find corresponding development along this line in municipal organization except by a few of the scattered Bureaus of Municipal Research. These results, also, have related to a few of the more common and general factors, such as determining the cost per mile, or per square yard, of street cleaned, or per million gallons of water pumped.

The cost of the management of water-works, one of the largest factors of public enterprise, has never been investigated extensively and thoroughly. There is much possibility in planning for greater efficiency and in determining what can be accomplished under economical administration. Every one is aware of the multiplicity of men in municipal service. Some of these are entirely incompetent, others partly so; the recent appointees may be more efficient, but the majority of them gradually deteriorate under the subtle influence of the prevailing atmosphere, and each new incoming administration places more and more men on the work, without reason or necessity. All these tendencies have made the cost and maintenance of public work greater and greater, and, at the same time, have resulted in frequently and steadily decreasing the output and efficiency per employee.

The Washington situation, however, presents an admirable contrast to this, because of the methods of administration of the public works of the District of Columbia and their freedom from petty political influence. The limited number of employees has tended toward economy, and rendered this plant the envy of all who have desired to obtain good management. Its cost items have been looked on as a result long hoped for, but seldom obtained. It is to be regretted, therefore, that such an abrupt change in methods of removing clogging material and replacing sand has taken place without years of experimental trial on filters not furnishing drinking water to the public, and without an attempt, under such excellent conditions, to maintain the efficiency by a better labor output and by improved working and machine methods in the performance of the older and established order of doing things.

In preparing water for the use of the people, the realms of the unknown are so much larger than those which have been investigated and developed that there may be many undiscovered factors affecting the public health, and many ways in which it is dangerous to depart from well-known and surely safe methods. Who can say that in some subtle and, at present, unknown manner, the failure in some places, where filtration is practiced, to reduce the death rate from typhoid fever may

not be due to the introduction of radical departures from the older, slower, safer, and more efficient methods which have produced such excellent results, both in America and in Europe? Further, in cases where there has been a falling off in the typhoid death rate, the failure to secure an accompanying improvement in general health conditions, which follows so closely in communities supplied by water filtered in accordance with the more conservative principles, may be due to the introduction of some of these not thoroughly tried processes. Some day full information may be available as to the influence of these methods of plant operation on the health of the community. Until that time, is it not a much better policy to follow the principles which have been proven by many years of experience to produce safe results, and to make the foremost object the improvement of the methods of operation in accordance with these established truths? Mr. Knowles.

There is opportunity for the upbuilding of greater efficiency in the conduct of employees and in securing the maximum output, by establishing more comfortable and healthful conditions than usually exist. The elimination of political influence from municipal service is also a task which challenges the people of to-day, and the operating and managing engineer is in a position to perform an important part in accomplishing this end. The number of employees can be reduced to those actually needed, and the way opened for the employment of men who thoroughly understand the necessities of honesty and efficiency in the conduct of public affairs. It should be rememebered that to design and construct well is only half the job; to operate economically and efficiently is even more of a problem than to build, and requires just as good talent, just as keen appreciation of the various problems, and is even more essential to public welfare. It seems to the writer that the logical development of the art of obtaining economy as well as efficiency should be along these lines, rather than to revolutionize methods, without having a long-period test of their value, and at the same time allow political influences to control, to a large extent, the labor item.

Preliminary Treatment.—The decision as to the preliminary treatment of the Potomac River water before filtration is of interest, particularly because various other conclusions have been reached in different sections of the country. However, in the main, these decisions have been due to differences in the character of the waters, but it must be evident that they have sometimes been the result of ill-considered action, or the desire to promote some special interest. The use of preliminary filters, which involves a large investment, is not always to be commended, particularly because at times of reasonably good water the removal of some of the organic matter is really injurious and lessens the effect of the final filters.

For a long time, the writer has believed that, where other things are equal, and where there is no important reason for double or prelimi-

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nary filtration, long periods of storage, accompanied by the use of coagulant at times of severe and extreme muddiness, as planned at Washington, solves the problem in the most practical and economical way. It is true that the investment for a large storage basin may equal, or even exceed, that required for preliminary filters; but the influence of storage on the quality of raw water is never injurious, and, by ripening the condition of the water, may be greatly beneficial in the process of filtration.

The storage available in such a basin makes it possible to shut off the supply from the river during the worst conditions of the water. The duration of the most troublesome spells ordinarily does not exceed a few days, and it is usually possible to secure sufficient capacity in the basin to tide over these periods. Then again, long periods of storage, in addition to assisting in breaking up organic matter, permit the dying out of bacteria, particularly many of the pathogenic kind, and, therefore, the water is rendered much safer from this standpoint. In other words, there is additional insurance in long storage against the faulty and careless operation of incompetent filter employees. The addition of coagulant, especially the fact that only a very small investment of capital is required for the necessary apparatus for dosing the water, and that the cost of the coagulating materials has to be met only when used, seems to give the process, in a most satisfactory manner, the requirement for economical management and thoroughness in preparing the water for final filtration.

Parking Public Works.—It is disappointing that the author has not mentioned some of the steps contemplated in reference to the landscape treatment of the Washington filtration area. Probably every one has been impressed by the barren aspect of the works as they are approached, and as one looks over them. Recently, however, it is stated that some steps have been taken to lay out the grounds, treat the surface in an attractive manner, and make a park of the area. The writer has a firm opinion that when an investment is made for public works, it costs but little in addition to construct buildings along appropriate architectural lines, to treat the grounds in a pleasing manner, and to make the entire works a credit to the municipality from an artistic standpoint. When treated on broad lines, such areas become public parks, and afford open breathing places for the residents, and, if near centers of population, may well be equipped with playground facilities for the children. When thus developed they should have care, that the planting and equipment should not deteriorate and the last state become worse than the first.

The influence which these ever-present examples of attractiveness have on the community is becoming better recognized by students of social progress, and there seems to be no doubt that spending money on such features is not only desirable from the artistic standpoint, but

is justified on practical grounds as well. It is cheaper than to create parks, when necessity and demand can no longer be resisted, by buying property and occasionally tearing down buildings and constructing *de novo*. That this work is now being done in Washington, even after construction, is certainly a recognition of the advisability of original efforts in this direction. Mr. Knowles.

GEORGE C. WHIPPLE, M. AM. SOC. C. E. (by letter).—Mr. Hardy's paper is an excellent presentation of the results of the operation of the Washington water filtration plant from the time of its construction in 1905 until June, 1910. Papers of this character are altogether too infrequent, and the actual results from the filters now in use are not readily accessible in detailed form. Yet it is only by studying the results obtained by filters in actual use that improvements can be made and the art advanced. Mr. Whipple.

Among the many important facts brought out by Mr. Hardy, only a few can be selected for discussion. One of these is the operation of filters under winter conditions. It is well known that the efficiency of sedimentation basins and filters is lower during winter than at other times, yet it is just at this season of the year that there is the greatest danger of typhoid fever and similar water-borne diseases being transmitted by water. Most of the great typhoid epidemics have occurred during cold weather, and the very use of the term "winter cholera" is of significance. Apparently, typhoid bacilli and similar bacteria are capable of living and retaining their vitality longest during that season of the year. Just why this is so, bacteriologists have not satisfactorily explained. Doubtless many factors are involved. Because of the increased viscosity of the water, sedimentation takes place less readily at lower temperatures, and inasmuch as sand filtration is partly dependent on sedimentation, the efficiency tends to fall off in cold weather. During winter some of the external destroying agencies are less potent, such as the sterilizing effect of sunlight, and the presence and activity of some of the larger forms of microscopic organisms which prey on the bacteria. Another factor may be the greater amount of dissolved oxygen normally present in water during cold weather, as experiments have shown that dissolved oxygen favors longevity.

Still another reason for the larger numbers of bacteria that pass through a water filter during cold weather may be the effect that the low temperature has on the size of the bacteria themselves. A few experiments made recently by the writer appear to indicate that at low temperatures the gelatinous membrane which surrounds the bacterial cells tends to become somewhat contracted, thus decreasing the apparent size of the bacteria as seen under the microscope. Either this contraction occurs, or the cells themselves are smaller when they

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develop in the cold. It is possible also that low temperature affects the flagella of the organisms in the same way. It is not unreasonable to suppose that the effect of low temperature is to form what may be, in effect, a protective coating around the cells, which tends to make them smaller, less sticky, and less subject to outside influences. This would tend to make them pass through a filter more readily. In line with this idea also is the well-known fact that disinfection is less efficient in cold water than in warm water.

Another way of viewing the matter is that cold retards the growth of bacteria on the filter, thus reducing the effect of the *Schmutzdecke*. Still another view of the greater danger from bacterial contamination in winter is the theory that cold prolongs the life of the bacteria by merely preventing them from living through their life cycle and reaching natural old age and death as rapidly as in warm weather.

Another topic in Mr. Hardy's paper which has interested the writer is that of preliminary filters. The experiments described at length indicate clearly that such devices would prove of little or no benefit under the conditions existing in Washington, and that when the river contains considerable amounts of suspended clay nothing less than chemical coagulation will suffice to treat the water so that the effluent will be perfectly clear. Preliminary filters have been used for a number of years at various places and with varying success. In few instances have they been operated for a sufficient length of time or been studied with sufficient care to determine fully their economy and efficiency as compared with other possible methods of preliminary treatment.

Among other experiments on this matter are those made at Albany, N. Y., and published by Wallace Greenalch, Assoc. M. Am. Soc. C. E., in the Fifty-ninth Annual Report of the Bureau of Water for the year ending September 30th, 1909. The Hudson River water used at Albany is quite different in character from the Potomac River water used at Washington, as it is less turbid and contains rather more organic matter. The results obtained in these experiments showed that during the summer the number of bacteria in the effluent from the experimental sand filter used in connection with a preliminary filter did not differ widely from the number found in the effluent of the city filter where there was no other preliminary treatment than sedimentation. In the winter, however, the numbers of bacteria did not increase in the effluent from the experimental filter as they did in the effluent from the city filter. This is shown by Table 26, taken from the report mentioned.

Apparently, therefore, at Albany the benefits of the preliminary filter, as far as bacterial efficiency is concerned, would be confined to a short period of three or four months in each year. Under such cir-

cumstances it may well be questioned whether the advantages of preliminary filtration justify its cost. Mr. Whipple.

TABLE 26.—Results of Experiments with Preliminary Filter at Albany, N. Y.

Month, 1906.	Bacteria in raw water.	Bacteria in preliminary filter effluent.	Bacteria in effluent from experimental sand filter.	Bacteria in effluent from city filter.
March	133 480	36 000	151	706
April	77 420	4 810	72	155
May	15 800	2 250	48	37
June	4 520	358	38	34
July	2 090	163	25	22
August	2 740	121	36	23
September	8 280	445	20	24
October	38 350	4 235	67	227
November	67 910	15 570	337	341
December	645 500	25 440	144	2 783
1907.				
January	127 560	4 660	48	443
February	28 000	1 800	13	116

On the diagram, Fig. 11, will be found various data taken from the published records of the Albany filter, from 1899 to 1909. These data include: The numbers of bacteria before and after filtration; the percentage of bacteria remaining in the effluent; the average quantity of water filtered, in millions of gallons per day; the quantities of water filtered between scrapings; the turbidity of the raw water; the cost of filtration, including capital charges and cost of operation; and the typhoid death rates of the city per month. Several points are brought out conspicuously by this diagram. One is the uniformly low death rate from typhoid throughout the entire period. The filter was operated from 1899 until the fall of 1907 with raw water taken from what is known as the "Back Channel." Since then it has been taken from a new intake which extends into the Hudson River itself. Until the fall of 1908 the preliminary treatment consisted merely of sedimentation, but since then the water has received an additional preliminary treatment in mechanical filters operated without coagulant, along the lines of the experiments just mentioned. During this time the average rate of filtration of the sand filter has not changed materially, although it is said that the maximum rate has been increased since the preliminary filters were put in service. The study of the bacteriological analyses shows that the best results were obtained during 1902, 1903, and 1904. Since then the numbers of bacteria in both the raw and filtered water have increased. This was especially noticeable during the winters of 1907 and 1908 when the water was taken from the new intake. It will be interesting to compare the

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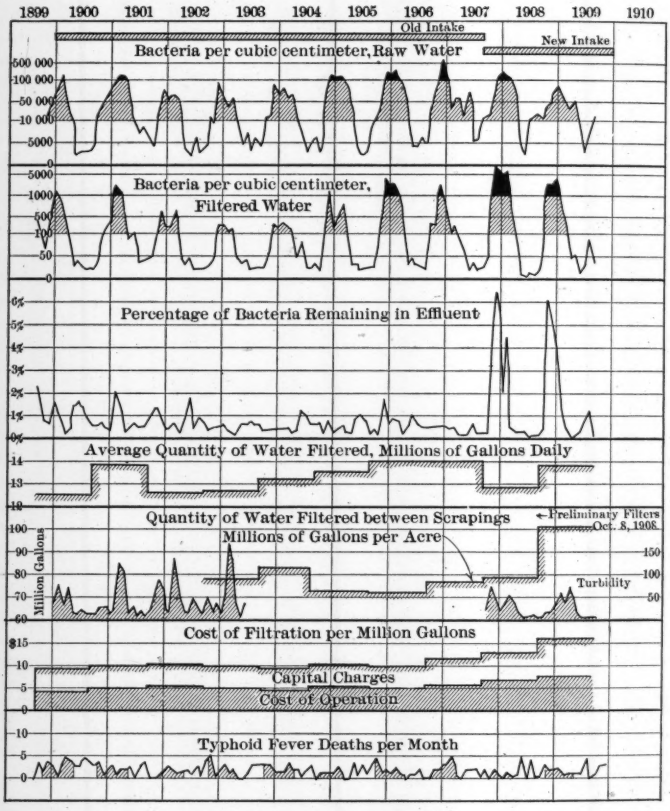
results after the preliminary filters have been operated for a long enough period to ascertain their normal effect on efficiency and on the increased yield.



FILTERS AT ALBANY, N.Y.
RESULTS OF OPERATION,
1899-1909.
Compiled from data in Annual Reports

FIG. 11.

Another fact to be drawn from the plotted Albany data is the increase in the cost of filtration, both in capital charges and in operation. From 1899 until 1906 the cost of operation, including the cost of low-lift pumping, was approximately $5 per million gallons of

water filtered; and the total cost of filtration, including capital charges, was about $10 per million gallons. During the year ending September 30th, 1909, the cost of operation had increased to $7.63 per million gallons, and the total cost of filtration to $15.92 per million gallons, or approximately 50% in three years. Mr. Whipple.

TABLE 27.—Results of Bacteriological Analyses of Samples of Water at Peekskill, N. Y., Before and After Filtration.

Bacteria per cubic centimeter.

Date.	Raw water.	Clear reservoir.	Effluent No. 1.	Effluent No. 2.	Effluent No. 3.	Effluent No. 4.	Tap in city.
1909.							
December 29th.....	190	100	..	..	..	..	..
1910.							
February 15th.....	135	10	10	30	20	..	265
March 31st.....	225	50	25	45	60	..	35
May 18th.....	300	29	22	26	35	43	36
July 6th.....	300	44	9	3	41	10	31
August 16th.....	60	5	0	4	1	13	15
October 3d.....	550	14	12	14	38	..	..
November 21st.....	315	22	26	17	6	..	..
1911.							
January 25th.....	415	7	8	4	6	..	7
Average.....	277	30	14	16	26	22	65

Tests for *B. Coli*.

Quantity of water tested.	Percentage of Samples Containing *B. Coli*.	
	Raw.	Filtered.
0.1 cu. cm.....	0	0
1.0 cu. cm.....	20	0
10.0 cu. cm.....	40	0

As a matter of record, the results of a series of analyses made at Peekskill, N. Y., during 1910 are presented in Table 27. A sand filter was constructed for the water supply of this city in 1909, and put in operation in December. The filter has a capacity of 4 000 000 gal. per day. The supply is taken from Peekskill Creek, and the water receives about one week's nominal storage before flowing to the filters. An aerator is used before filtration during the summer, when algæ are likely to develop in the reservoir. The filter was installed after an epidemic of typhoid which was apparently caused by an infection of the water supply. Normally, the water has been little contaminated, but the supply is subject to accidental contamination at any

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time, among other possible sources of infection being the camps of workmen now engaged in constructing the Catskill Aqueduct for New York City.

TABLE 28.—AVERAGE RESULTS OF CHEMICAL ANALYSES AT PEEKSKILL, N. Y., MADE AT INTERVALS OF SIX WEEKS DURING 1910.

	PARTS PER MILLION.			PARTS PER MILLION.	
	Raw water.	Filtered water.		Raw water.	Filtered water.
Turbidity	2.	0	Total residue	70.	76.00
Color	25.	20.	Loss on ignition	19.00	17.00
Nitrogen as albuminoid ammonia	0.112	0.076	Fixed residue	50.00	59.00
Nitrogen as free ammonia	0.024	0.006	Iron	0.17	0.13
Nitrogen as nitrites	0.001	0.001	Total hardness	38.70	45.10
Nitrogen as nitrates	0.06	0.06	Alkalinity	33.90	42.60
			Incrustants	4.60	4.50
			Chlorine	2.60	2.70

Mr. Longley.

F. F. LONGLEY, ASSOC. M. AM. SOC. C. E. (by letter).—In this paper the author has presented a mass of data which will be welcomed by engineers engaged in water purification work, because complete operating records form a substantial basis for improvement in the art, and are often the inspiration for interesting discussions and the exchange of experiences of different observers whose views are mutually appreciated.

Recent tendencies in filtration engineering have been largely in the direction of reducing the cost of operation. A comparison of the operating costs of the earlier American plants of about a decade ago, with those here presented of the Washington plant, is very gratifying to those who have been intimately connected with the latter work. Through perfection in design and reasonable care in operation, the cost of filter cleaning, which is a very considerable part of the total cost, has been reduced to an unusually low figure, without any sacrifice in efficiency, and in the interests of the public health.

Table 14 shows that, from the first year, there has been a progressive increase in the total cost of operation per million gallons filtered, but this has not meant an increase in the annual total expenditure. The largest percentage of increase in any item has been in "Care of Grounds and Parking," and covers much-desired landscape improvements. Aside from this, the principal factor affecting the table of costs has been the reduction in water consumption in the District of Columbia. Nothing pertaining to this reduction has produced any corresponding reduction in the force required for the maintenance and operation of the filtration plant, office and laboratory, and pumping station, though probably there has been some reduction in filter cleaning. Obviously, then, the total cost per million gallons would increase.

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This decrease in consumption has been brought about by the elimination of waste in the distribution system, which is not in the same department as the filtration plant, but with regard to which a word may not be amiss in connection with this discussion.

The Washington Aqueduct was built half a century ago on lines which at that time were considered extraordinarily generous. Until recently, therefore, there has been no occasion for concern over the high rate of consumption. During recent years, however, the use and waste of water have increased, reaching a climax under unusual conditions in the winter of 1904-05. The maximum capacity of the aqueduct system is about 90 000 000 gal. The maximum daily consumption at the time mentioned arose almost to 100 000 000 gal., with the result that, before normal conditions were restored, the reservoirs of the system were almost depleted.

This had a beneficial effect, as provision was made for an active campaign for reducing the waste of water, which was known to be very large. These investigations, using the pitometer, were begun in July, 1906, and have been pursued continuously since that time, with most excellent results. Up to January, 1909, leaks aggregating about 12 000 000 gal. per day were detected and eliminated, and about half the house services had still to be covered by the pitometer bureau.

Although this reduction in waste has brought about an apparent increase in the cost of filtration, its economical results have been far-reaching. The causes which brought about this investigation also resulted in securing an appropriation for the study of the question of increased supply. The writer was in charge of these studies, and the most significant conclusion was that, owing to the excellent results of the efforts for waste restriction, the total consumption and waste of water in the district during the next few years would be far enough below the safe working capacity of the existing aqueduct system to make it entirely safe to postpone the construction of new works, involving the expenditure of several million dollars, in spite of the threatening conditions of a few years ago.

There has been so much controversy over typhoid fever in the District of Columbia that the writer hesitates to discuss this subject. Viewing the situation through the perspective of several years, however, it does not seem to be as hopeless as the criticisms of four or five years ago would lead one to believe.

In Table 9, showing the typhoid death rates, out of nine years given prior to 1905-06, when the filters were started in operation, only one shows an annual death rate as low as the highest one since that year. Further than this, the annual average typhoid death rate for the period since that year has been one-third lower than for a corresponding period before the filters were started.

The exhaustive researches of the Public Health and Marine Hospital Service into this whole question, covering a period of about

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four years, have raised the present filtered water supply of the District of Columbia above any well-founded criticism. There has long been a strong and growing feeling that the water supply, before filtration was introduced, had been blamed for more than its share of the typhoid, and this is borne out by much evidence that has been presented from time to time.

It is not an unreasonable conjecture, therefore, that perhaps the reduction of one-third in the total typhoid death rate may represent a much larger reduction in that part of the total which was due to polluted water alone; and that, as the authorities in the District of Columbia and in certain other cities, particularly in the South, are now recognizing, the fight against much of the remaining typhoid must be in the direction of the improvement of milk supplies, precautions against secondary infection, and attention to a large number of details surrounding the individual, which may effectively protect him against the insidious attack of the disease favored by unknown agencies.

Experiments in Filter Cleaning.

The author refers to the difficulty encountered during the first two summers in keeping the filters cleaned fast enough to maintain the capacity of the plant. The real seriousness of this may be judged from the following facts. The average increase in loss of head on all the filters for the entire year, July 1st, 1906, to July 1st, 1907, was about 0.053 ft. per day. During the 1906 period of low capacity under discussion, the loss of head on twelve of the filters increased for a period of eight days at the average rate of 0.45 ft. per day, or about nine times the normal rate of increase. This difficulty was caused by the presence of large numbers of micro-organisms in the applied water. During the first summer (1906) this fact was not recognized, but the sudden decrease in capacity was supposed to have been caused by the unusually high and long-continued turbidity which prevailed during that summer in the Potomac River, and persisted in the water supplied to the filters even after about four days of sedimentation in the reservoirs. During the second summer (1907) the same phenomenon of suddenly and rapidly increasing losses of head appeared again, but without any unusual turbidity in the applied water. Investigation, however, showed the presence of large quantities of organisms, particularly *melosira* and *synedra*, in the applied water, and examinations in subsequent years have shown a periodic recurrence of these forms in quantities sufficient to cause the trouble mentioned. In June, 1907, examination showed repeatedly more than 1 000 and 1 500 standard units of *melosira* per cu. cm., and one count showed nearly 3 000 standard units.

Several expedients were tried in an effort to restore the rapidly decreasing capacity of the filters. One of the earlier conjectures as to

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the cause of the trouble was that it might be due to the accumulation of large quantities of air under the surface of the sand, as air had been observed bubbling up through the sand, especially in filters which had been in service for some time. The expedient was tried, therefore, of draining the water out of the sand and then re-filling the filter in the usual manner from below, in the hope of driving out the entrained air. Presumably this treatment got rid of the air, but it did not restore the capacity of the filter, as the point of maximum resistance was in the surface of the sand and not below it.

As the author states, raking the filters was tried and found to give results which were satisfactory enough to meet the emergencies already referred to. When the filters were first put in operation, in the fall of 1905, the method of bringing back the capacity of a filter after the end of a run was to remove all the dirty sand to a depth determined by the marked discoloration caused by the penetration of the clay turbidity. This sometimes necessitated the removal of large quantities of sand at a cleaning, as the turbidity was exceedingly fine, and penetrated at times to a depth of 3 or 4 in.

With the idea of effecting an economy in the cost of cleaning the filters, a schedule of experiments was arranged shortly before July 1st, 1907. The general object of the experiments was to determine, first, the relative costs of all different methods tried; second, whether the removal of only a thin layer of sand, or the mere breaking up of the surface of the sand by thorough raking, would give the filter its proper capacity for the succeeding run; third, whether the filters under these treatments would maintain a high standard of quality in the effluents; fourth, whether the continued application of any less thorough method than the one then in use might materially affect the future capacity of the filters.

To this end the filters were divided into four groups which, during a period of about six months, were subjected to treatments as follows:

Group *A*.—Filters scraped deep at the end of each run;
" *B*.—Filters scraped light at the end of each run;
" *C*.—Filters raked at the end of each run, until raking failed to bring back the proper capacity; then they were scraped light, and at the end of the next run the raking was resumed;
" *D*.—Light scrapings and rakings alternate at ends of runs.

The term "deep scraping" means the removal of practically all the discolored sand, in accordance with the usual practice prior to the beginning of these experiments; "light scraping" means the removal of only a thin surface layer of sand. This depth has usually averaged about $\frac{3}{4}$ in. "Raking" means the thorough breaking up of the clogged surface of the filter by iron-toothed rakes, to a depth of about 1 or 2 in.

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Results.—A general summary of the results of these experiments is given in Table 29, which also shows the relative costs of the different methods per million gallons of water filtered. A normal period of 9 months just prior to the beginning of these experiments shows a labor cost (corresponding to that in Table 29) of \$0.29¼ per million gallons filtered.

TABLE 29.—AVERAGE RESULTS.

	Per Run:					Per Million Gallons Filtered:			
Group.	Number of filters.	Number of days of service.	Million gallons filtered.	Cost of labor per treatment.	Sand removed, in cubic yards.	Sand removed in cubic yards.	Cost of labor.	Bacteria per cu. cm. in effluent.	Turbidity in effluent.
A	5	82	221.2	\$68.44	245	1.11	\$0.309	13	1
B	9	36	101.4	29.25	84	0.83	0.288	16	1
C	5	21	60.0	10.92	24	0.40	0.182	18	1
D	10	32	86.0	20.10	46	0.54	0.234	22	1

Capacity of Filters.—The capacity of the filters under the different methods of treatment are shown in a general way in Table 29 for days of service and millions of gallons filtered per run. This element by itself is decidedly in favor of the deep scrapings, and least in favor of the repeated rakings.

A clearer conception of the capacities of the filters under these different conditions may be obtained from the four diagrams, Fig. 12, showing, for the four different groups, the average number of days of service of the successive runs. The diagram for Group *A* shows that the variations in the period of service of the filters scraped each time to clean sand follow a more or less definite curve from year to year. For the period covered by this curve, the tendency seems to be toward a slight decrease in capacity from year to year, as shown by the lower average maximum and minimum in the second year than in the first. Group *B* shows a sudden decrease in capacity following the first light scrapings and, since that time, a low but quite constant capacity. Group *C* shows a constantly decreasing capacity with successive rakings. The only significance attaching to the curve after the first raking is the prohibitively low capacity indicated, and the ineffectiveness of the measures taken to restore the capacity after the sixth raking. Group *D*, after the first raking, shows a prohibitively low and constantly decreasing capacity. The diagrams for *C* and *D* indicate a dangerous reduction in capacity if long persisted in. The method followed with Group *C* may be dismissed with the statement that it is entirely insufficient, and would be of use only in the rarest emergencies.

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As far as the question of capacity is concerned, these diagrams indicate that a filter in normal condition may safely be raked once. It is believed that the constantly decreasing capacity shown in Group *D* is not due so much to the rakings as to the small quantities of sand removed at the alternate scrapings, and therefore it would not be proper to condemn this method of treatment without a further

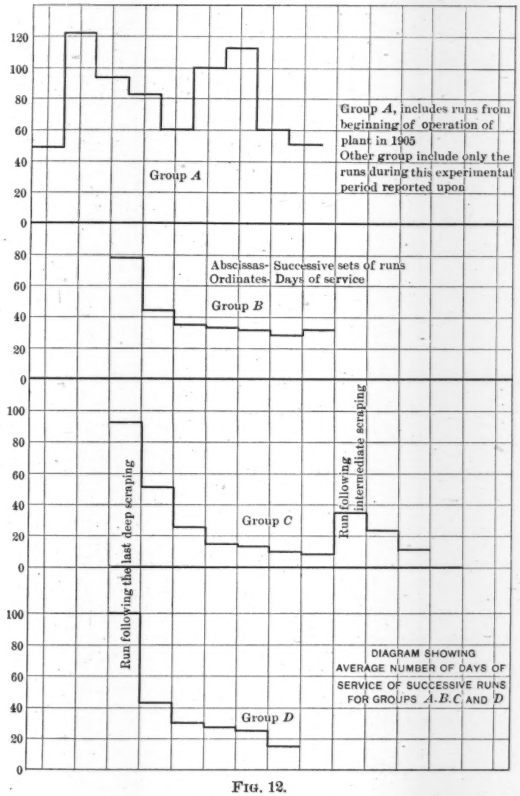

FIG. 12.

trial in which this defect was remedied. This view seems to be supported by the results of Group *B*. The low but approximately constant capacity there shown would undoubtedly have been higher if a greater depth of sand had been removed each time.

Quality of the Effluent.—The averages given in Table 29 show but little difference in the bacterial contents of the effluents from the four

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groups of filters. All are entirely satisfactory, and the differences in favor of one method or another are small. In looking for possible differences in the quality of the effluents from the four groups, it was thought that such differences might be most apparent at a time when the entire plant was working under the most adverse conditions. The bacterial counts, therefore, were summarized for the period from December 23d, 1907, to January 6th, 1908, inclusive, following a period of high turbidity and high bacteria in the raw water, with results as follows:

Group	*A*	*B*	*C*	*D*
Maximum	204	178	189	206
Minimum	61	45	62	57
Average	120	107	104	155

The following is a summary of the turbidity results for a similar period:

Group	*A*	*B*	*C*	*D*
Maximum	10.8	11.7	8.7	9.3
Minimum	6.7	4.7	6.2	5.7
Average	8.7	8.3	7.2	7.9

These numbers, though high, do not show any significant differences. All the averages for each group are less than the lowest maximum, and all are greater than the highest minimum, and therefore vary less than do the individual filters, from other causes, within the different groups.

Future Capacity of the Filters.—An indication of the dangers which might affect the future capacity of the filters was shown in the above discussion of the present capacity. A more effective way of showing this was obtained by a study of the initial resistances or losses of head in the four groups. A filter kept in ideal condition would show no increase in this initial loss of head from one run to the next. If there is such an increase, it means that at some future time measures more heroic than ordinarily used would be necessary to restore the proper capacity.

The average initial losses of head for the different groups are plotted on the diagram, Fig. 13. Group *A* shows an initial loss of head, increasing gradually but slightly during more than two years of service. In Group *B* the initial loss of head increased in a manner similar to that in Group *A*, up to the time of the beginning of these experiments; after which the increase becomes more rapid. Groups *C* and *D* show conditions generally similar to Group *B*, with some variations which are self-explanatory.

Conclusions.—The quality of the effluents from all four groups was satisfactory, and no consistent difference was apparent in favor of one or another method of treatment. The method pursued with Group *C* was entirely insufficient to maintain the capacity indefinitely.

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The methods pursued in Groups *B* and *D* were both insufficient, but would have been more effective if a greater depth of sand had been removed. The costs of treatment of Groups *B* and *D* were less than for Group *A*. It appears, then, that a treatment which would be more economical than the old method of Group *A*, and would still maintain the proper capacity, would be one similar to that of Groups *B* or *D*, with the removal of a quantity of sand greater than was done in the case of these two groups, but less than in the old method.

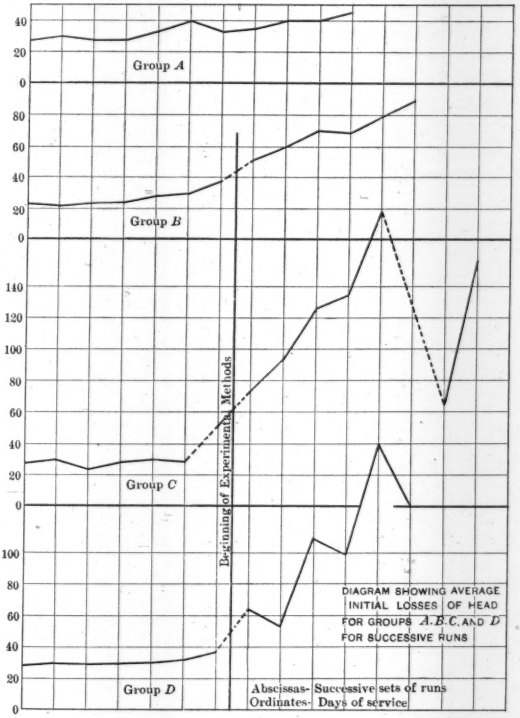

FIG. 13.

At the time the above results were summarized, it was proposed to proceed with the filter treatment along the lines just mentioned. The writer did not have an opportunity to study the subsequent results, as he was transferred to other work. A statement by the author of any new facts that may have come to light in this connection would be of interest.

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Mention should be made, too, of another expedient that was used to hasten the restoration of the capacity of a filter, which proved to be a most useful one. The removal of the scraped sand from a filter was a matter of a good many hours' work, under the most favorable conditions. To get the filters quickly into service again, the dirty sand in a number of them was simply scraped from the surface, heaped into piles, and left there; then the water was turned in, and the filter was started again. This was done with some hesitation at first for fear the presence of the piles of dirty sand might cause high bacterial counts in the effluents of those filters. No such effect was observed, however, the counts being entirely normal throughout. The writer subsequently found the same treatment being applied as an emergency measure at the Torresdale plant, in Philadelphia, and, through the courtesy of the Chief Engineer of the Bureau of Filtration, was furnished with the bacterial counts through a number of runs made under these conditions, and there, too, the results were entirely normal.

There was practically no economy in this method, as the sand had ultimately to be ejected and washed. The piling up of the sand had the effect of reducing the effective filtering area by a small percentage, with a corresponding increase in the actual rate of filtration, but this was of trifling importance. The great benefit derived from the method was the saving of time in getting a filter back into service after scraping, and in this respect it was very valuable.

Physical Theory of Purification of Water by Slow Sand Filters.

The first and most natural conception of the action of a sand filter is that the removal of impurities is effected by a straining action. This, of course, is perfectly true as far as it relates to a large part of the visible impurities. Much of this is gross enough to be intercepted and held at the surface of the sand. This very straining action is an accumulative one. After a quantity of suspended matter thus strained out mats itself on the surface of the sand, it in turn becomes a strainer, even better adapted than the clean sand surface which supports it for the removal of suspended matter from the water.

This, however, cannot explain certain features of the purification of water by a layer of sand. The removal of color, the reduction of nitrates, and certain other changes in the organic content of the water have for a long time been recognized as due to a bio-chemical action carried on by certain bacteria in the sand. Both the straining action and this bio-chemical action are not all-sufficient for the explanation of certain phenomena, and it has been recognized, too, that sedimentation in the pores of the sand played a large part in the purification process in those cases in which it was apparent that the biological agencies were not the chief ones.

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In the purification of water containing only insignificant quantities of suspended matter, but a relatively large amount of unstable organic matter, it will be conceded at once that the chief factor in the purification is the nitrification produced by the bacteria in the upper layers of the sand. On the other hand, the purification by sand filters of a hypothetical water containing no organic matter, but only finely-divided mineral matter in suspension, could take place only by the physical deposition of the particles upon the sand grains. Between these two extremes lie all classes of water. In all problems of water purification by filtration through sand, both these factors—biological action and sedimentation—play their parts, assisting and supplementing each other, the relative importance of one factor or the other depending on the place of the particular water in question on the scale between the two extreme conditions just mentioned.

In Mr. Hazen's paper on "Sedimentation"* there is an interesting development of the theory of the removal of suspended matter by sedimentation in the pores of a layer of sand. The factors influencing this removal are the rate of filtration, the effective size of the sand, and the temperature of the water. For the conditions at the Washington plant, it may be assumed that the first two of these factors are constant. The third factor, however, varies through wide limits, and the observations on the turbidity removal, and on the different phases of the filter operation of which the turbidity of the water is a factor under varying temperature conditions, together with the known relations between hydraulic values and temperatures of water, furnished good substantiative evidence that this highly-induced sedimentation may be a considerable factor in the purification of the water as effected at this plant. This temperature relation, briefly stated, is as follows: For particles of a size so small that the viscosity of the water is the controlling factor in determining the velocity of their subsidence in still water, that velocity will vary directly as $\frac{T+10}{60}$, in which T is the temperature, in degrees, Fahrenheit. That is, when the temperature of the water is between 70° and 80° Fahr., a particle will settle with twice the velocity it would have if the water were near the freezing point.

The layer of sand in a slow sand filter may be considered as a very great number of small sedimentation basins communicating one with another, not in the manner of basins connected in series, but rather, as Mr. Hazen has expressed it, as a long series of compartments connected at one side only with a passageway in which a current is maintained. In any section of the sand layer there are areas through which the water passes with a velocity much greater than its mean velocity through the total area of voids, while there

* *Transactions*, Am. Soc. C. E., Vol. LIII, p. 59.

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are other areas in which the velocity is very much less, perhaps in an almost quiescent state from time to time, greatly favoring the deposition of particles, but with a gentle intermittent circulation, displacing the settled or partly-settled water and supplying from the main currents water containing more suspended matter particles to be removed. There is thus a considerable percentage of the total volume of voids in which the water is subjected to very favorable conditions for sedimentation, almost perfect stillness and an exceedingly small distance for a particle to settle before it strikes bottom on the surface of a grain of sand.

If sedimentation were the predominating factor in the purification of the water, we would then expect to find the following phenomena in the operation of the filters: A more rapid deposition of a given amount of sediment under summer temperature conditions than under winter, as the water passes through the sand, and therefore, for the former condition of higher temperature:

(*a*) A greater concentration of this turbidity-producing material in the top layer of sand, or, in other words, a thinner sand layer to be removed in scraping if all the dirty sand is removed;
(*b*) Because of the greater concentration, a greater rate of increase of the loss of head, and consequently shorter periods of service between scrapings;
(*c*) A higher limit for turbidity in the water applied to the filter to produce a given turbidity in the effluent.

The operation of this plant during the first year and a half offered an excellent opportunity for the study of sedimentation in the sand, and the data in Table 30 are presented to show that certain of the phenomena of filter operation observed during this period

TABLE 30.—SERVICE PERIODS AND SCRAPING DEPTHS FOR RUNS ENDING IN VARIOUS MONTHS; COVERING ENTIRE PERIOD, OCTOBER 1ST, 1905, TO MARCH 1ST, 1907.

Month.	Number of filters.	Average period of service, in days.	Average depth of sand removed, in inches.	Mean temperature, in degrees, Fahrenheit.
January	13	75	2.09	39
February	6	98	2.46	37
March	5	130	2.66	41
April	8	149	2.96	53
May	7	130	2.80	67
June	11	124	2.85	77
July	17	70	2.12	81
August	2	49	1.98	80
September	5	73	2.48	76
October	37	70	1.56	64
November	20	42	0.81	49
December	14	57	0.94	40

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seem to be fairly explicable by the physical theory of purification. These data are given only for the period of operation before the summer of 1907. At that time the experiments in filter cleaning already described were begun. Before that time, whenever a filter had been cleaned, all the discolored sand had been removed, leaving for the following run a new sand surface substantially in the perfect condition of a newly-constructed filter. After that time the experimental methods of cleaning, and the new routine adopted as a result thereof, interfered with the tracing of the evidence as clearly as during the earlier periods.

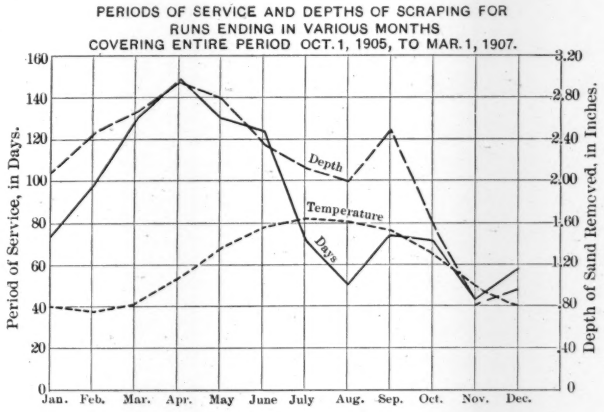

FIG. 14.

Table 30 and the corresponding diagram, Fig. 14, show the general variations in the length of runs and depth of penetration, with the seasonal temperature changes. The increase in length of runs and quantity of sand removed under low temperature conditions is very marked. There is, however, a secondary maximum which appears, as the diagram shows, where a minimum for the year would be expected. This may have been an irregularity occurring this one year, which will not appear in the average of several years, and caused by some factor which has escaped observation. A careful analysis of the data at hand fails to show any explanation for it. It may exist in some of the little-understood biological actions which have their maximum effect under warm-water conditions, or it may be due—in some obscure way—to the liberation of air under the surface of the sand, accumulating with pressure enough to break the surface at innumerable points, thereby reducing the loss of head and extending the period

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of service. Some evidence was observed pointing to this explanation, but it was never conclusively proven.

The general effect of temperature changes on the rapidity of removal of the sediment and its consequent concentration in the sand layer, however, seems plainly evident.

In corroboration of the third point mentioned in the theoretical consideration of turbidity removal in the filters, the daily turbidities of the filtered water have been classified and summarized for different turbidities in the applied water, and also for different temperatures. The average turbidities thus obtained are given in Table 31.

TABLE 31.—TURBIDITY IN FILTERED WATER AT DIFFERENT TEMPERATURES PRODUCED BY GIVEN TURBIDITY IN APPLIED WATER.

Turbidity of applied water.	TEMPERATURE, IN DEGREES, FAHRENHEIT.				
	< 40°	40°–50°	50°–60°	60°–70°	> 70°
20	1.8	1.3	1.2	1.5	1.7
20 – 40	4.8	5.0	3.5	3.0	2.6
40 – 60	7.9	6.9	5.4	....	3.7
60 – 80	10.7	7.7	....	....	5.4
80 –100	11.3	....	....	....	....
100	....	....	....	....	12.0*

* For an average turbidity = 150, approximately.

The influence of the temperature of the water on the turbidity of the effluent is very pronounced. For a temperature of less than 40° Fahr. (actual average temperature about 35°), the turbidity of the filtered water for a given turbidity of the applied water is practically twice as great as for a temperature greater than 70° (actual average temperature about 75°). This fact fits in very nicely with the influence of temperature on sedimentation. Referring again to this temperature relation, as set forth on a previous page, the hydraulic subsiding value of a particle in water, of a size so small that viscosity is the controlling factor in its downward velocity, is approximately twice as great at 75° as at 35 degrees. We would then expect to find that, in order to obtain a given turbidity in the filtered water, a raw water may be applied at 75°, having twice the turbidity of the water applied at 35°, to produce the same turbidity; and further, as the turbidity of the filtered water, for a given temperature condition, varies quite directly in proportion to the turbidity in the applied water, it follows that an applied water of given turbidity will produce an effluent at 35° with a turbidity twice as great as at 75 degrees. This is quite in accordance with the facts obtained in actual operation, as indicated on the diagram, Fig. 15.

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Preliminary Treatment of the Water.—The most striking features of the bacterial results given in Table 4 are, first, the uniformly low numbers of bacteria in the filtered water during perhaps 8 or 9 months of the year, and the increase in numbers each winter. This is shown clearly in the analysis of bacterial counts in Table 32.

TABLE 32.—CLASSIFICATION OF DAILY BACTERIAL COUNTS IN THE FILTERED-WATER RESERVOIR DURING THE PERIOD, NOVEMBER 1ST, 1905, TO FEBRUARY 1ST, 1908.

Bacterial count between:	No. of days.	Percentage of whole.	
0 and 20 per cu. cm.	291	41.0	
20 and 40 per " "	245	34.6	
40 and 60 per " "	63	8.9	
60 and 80 per " "	30	4.2	
80 and 100 per " "	28	4.0	92.7
100 and 200 per " "	29	4.1	
200 and 300 per " "	13	1.8	
300 and 500 per " "	5	0.7	
500 and 1 000 per " "	5	0.7	7.3
			100.0

The tests for *Bacillus Coli* in Table 5 show results which correspond closely to these, with this organism detected only infrequently, except during the periods of high bacteria, and both of these are parallel to the turbidity variations in the filtered water. These variations follow closely the variations in the turbidity and in the bacterial content of the water applied to the filters.

By all standards of excellence, the sanitary quality of the water during the greater part of the time is beyond criticism. In view of the close parallelism of turbidity and bacterial results in the applied and in the filtered water, it is entirely logical to conclude that, if the quality of the applied water could be maintained continually through the winter as good as, or better than, it is during the summer, then the filtered water would be of the perfect sanitary quality desired throughout the entire year.

This was all foreseen ten years ago, when Messrs. Hering, Fuller, and Hazen recommended auxiliary works for preliminary treatment of the supply, although, as the author states, these works were not provided for in the original construction. As prejudice against the use of a coagulant seemed to be at the bottom of the opposition to the preliminary treatment, a campaign of education bearing on this point was instituted, in addition to the systematic studies of different preliminary methods to which the author refers. As a result of the combined efforts of all those interested in promoting this improvement, an appropriation was finally made for the work in 1910. The coagu-

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lating plant has since been built, and the writer is informed that coagulation was tried on a working scale a short time ago during a period of high turbidity. A statement of the results of this treatment on the purification of the water in the reservoir system and in the filter plant would be of great interest.

Hydraulic Replacing of Filter Sand.—The author has adopted a method of replacing clean sand in the filters which will commend itself to engineers as containing possibilities of economy in operation. The first experiments in the development of this method at the Washington plant were carried out some three years ago, while the writer was still there. Substantially the same methods were used

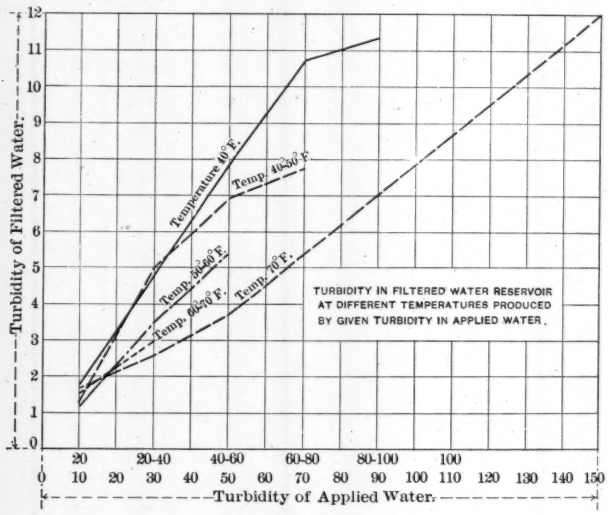

FIG. 15.

then as are described in this paper, but examination of the sand layer by cutting vertically downward through it after re-sanding in this manner showed such a persistent tendency toward the segregation of the coarse material as to hold out rather discouraging promises of success. The greatest degree of separation seemed to be caused by the wash of the stream discharging sand on the surface. It was observed that, near the point where the velocity of the stream was practically destroyed, there seemed to be a tendency to scour away the fine sand and leave the coarse material by itself, and pockets of this kind were found at many points throughout the sand layer. The author states that, in the recent treatment of the filters by this method, there has been no apparent tendency for the materials to separate into

different sizes, and it is fortunate if this work can be done in such a manner as to avoid this separation entirely. Mr. Longley.

It may be questioned whether a certain amount of segregation of the materials will make any practical difference in the efficiency of a filter. In all probability this depends on the degree of the segregation, the quantity of pollution in the water to be filtered, the rate of filtration, and the uniformity of methods followed in the operation, etc. For an applied water as excellent in quality as that of the Washington City Reservoir during favorable summer conditions, a considerable degree of segregation might exist without producing any diminution in efficiency. For a badly polluted water, however, such as the applied water at this plant during certain winter periods, or the water of a great many other polluted supplies, it might be found that even a slight lack of homogeneity in the sand might make an appreciable difference in the results of filtration.

As a result of the experiments herein described, however, this method may be applied at other plants where conditions seem to warrant it, with a largely increased measure of confidence; although, as in the case of the adoption of any new or radical departure, that confidence must not be permitted to foster contempt of the old and tried methods, but its operation must be watched with the utmost caution, until long experience shall have demonstrated its perfect suitability and defined its limitations.

E. D. HARDY, M. AM. SOC. C. E. (by letter).—It was not the writer's original intention to enter into a discussion of either the theory of water purification or of the experimental work on sand handling, but simply to present the main results of operation largely in tabular form. He is gratified, however, to have these sides of the question so ably brought out in Mr. Longley's discussion. Mr. Hardy.

Mr. Hazen referred to the inferior efficiencies of the experimental filters for rate studies (as shown in Table 20) in the removal of the *B. Coli* from the water tested. This inferiority is really less than the figures in the table would indicate, as the tests for the experimental filters were presumptive only (as shown by the note at the foot of Table 20), while those for the main filters were carried through all the confirmatory steps.

From experiments* made by Messrs. Longley and Baton in the writer's office, it would seem reasonable to assume that about one-half of the positive results would have been eliminated had the confirmatory steps been taken. In other words, the figures showing the number of positive tests for *B. Coli* in Table 20 should be divided by two when comparing them with corresponding ones for the main filters.

Mr. Knowles seems somewhat apprehensive regarding the methods described in the paper of restoring the capacity of the filters by raking,

* Published in the *Journal of Infectious Diseases*, Vol. 4, No. 3, June, 1907.

Mr. Hardy.

and replacing sand by the hydraulic method, and yet, from Mr. Johnson's discussion, it would seem that the practice of raking filters between scrapings had recently been adopted at the Pittsburg plant.

Before the practice of raking was finally adopted as a part of the routine filter operation, the subject was given a great deal of thought and study, as may be seen by referring to Mr. Longley's discussion.

The re-sanding has been done by the hydraulic method, for nearly two years, and, as far as the writer is able to judge, this method has been more economical and also more satisfactory in every way than the old one. As Mr. Hazen states, this does not prove that the hydraulic method would be as satisfactory for other filter plants and other grades of sand. The elevated sand bins at the Washington plant fit in well with this scheme, and save the expense of one shoveling of the sand; and the low uniformity coefficient of the sand is favorable in decreasing its tendency to separate into pockets or strata of coarse and fine sand. The method of washing is also well adapted to this method of re-sanding, as the sand is made very clean in its passage through the washers and storage bins. The hydraulic method of replacing sand tends to make it cleaner still, because any clay which may be left in the sand is constantly being carried away over the weir and out of the bed, to the sewer. Sand replaced by the hydraulic method is much more compact than when replaced by other methods, and consequently the depth of penetration of mud in a filter thus re-sanded is less. Careful tests of the effluents from filters which have been re-sanded by the two methods have invariably shown the superiority of the hydraulic method.

The experiment of replacing sand by water, referred to by Mr. Longley, was not considered a success at the time, and the method was abandoned for about a year. At that time an attempt was made to complete the re-sanding of a filter which had been nearly completed by the old method. The precaution of filling the filter with water was not taken, nor was any special device used for distributing the sand. When this method was again taken up, various experiments were tried before the present method was adopted.

Mr. Whipple's remarks on the results from the operation of filters under winter conditions are very interesting, and, considering his standing as an authority in such matters, they are worth careful consideration.

In the operation of the Washington plant, it has always been noticeable that the results were much poorer in winter than in summer. In fact, nearly all the unsatisfactory water which has been delivered to the city mains has been supplied during the winter months. On the other hand, the typhoid death rate has always been comparatively low in cold weather. These facts would seem to indicate that the water supply was not responsible for the typhoid conditions.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

TRANSACTIONS

Paper No. 1192

EXPERIMENTS ON RETAINING WALLS AND PRESSURES ON TUNNELS.

By William Cain, M. Am. Soc. C. E.

With Discussion by Messrs. J. R. Worcester, J. C. Meem, and William Cain.

The most extended experiments relating to retaining walls are those pertaining to retaining walls proper and the more elaborate ones on small rotating retaining boards. The results referring to the former agree fairly well with a rational theory, especially when the walls are several feet in height; but with the latter, many discrepancies occur, for which, hitherto, no explanation has been offered.

It will be the main object of this paper to show that the results of these experiments on small retaining boards can be harmonized with theory by including the influence of cohesion, which is neglected in deducing practical formulas. It will be found that the influence of cohesion is marked, because of the small size of the boards. This information should prove of value to future experimenters, for it will be shown that, as the height of the board or wall increases, the influence of cohesion becomes less and less, so that (for the usual dry sand filling) for heights, say, from 5 to 10 ft., it can be neglected altogether.

The result of the investigation will then be to give to the practical constructor more confidence in the theory of the sliding prism, which serves as the basis of the methods to follow.

As, in the course of this investigation, certain well-known constructions for ascertaining the pressure of any granular material against retaining walls will be needed, it is well to group them here. The various figures are supposed to represent sections at right angles to the inner faces of the walls with their backings of granular material. In the surcharged wall, Fig. 1, produce the inner face of the wall to meet the surface of the surcharge at F. It is desired to find the thrust against the plane, AF, for 1 lin. ft. of the wall. Draw AD through A, the foot of the wall, making the angle of repose, ϕ, of the earth with the horizontal and meeting the upper surface at D. Since any possible prism of rupture, as $FACR$, in tending to move downward, develops friction against both surfaces, AC and AF, the earth thrust on the wall will make an angle, ϕ', with the normal to AF, where ϕ' is the angle of friction of the earth on the wall. As the earth settles more than the wall, this friction will always be exerted. Again, as the wall, from its elasticity and that of the foundation, will tend to move over at the top on account of the earth thrust, the earth, with its frictional grip on the wall, will tend to prevent this, so that the friction is exerted downward in either case, and the direction of the earth thrust, E, on AF is as given in Fig. 1.

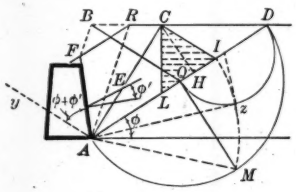

FIG. 1.

However, if $\phi' > \phi$, a thin slice of earth will move with the wall, and the rubbing will be that of earth on earth, so that ϕ' in this case must be replaced by ϕ. This rule will apply in all cases that follow, without further remark, wherever ϕ' is mentioned.

Now draw Ay, making the angle, $\phi + \phi'$, with AF, as shown; then draw FB parallel to AR, to the intersection, B, with DR produced. From B a parallel to Ay is constructed, meeting AD at O.

Since theory gives the relation: $AI = \sqrt{AD \cdot AO}$, two constructions follow, by geometry, for locating the point, I. By the first, a semicircle is described on AD as a diameter; at the point, O, a perpendicular is erected to AD, meeting the semicircle in M; then AI is laid off equal to the chord, AM. By the second construction, a semicircle is described on $O\,D$ as a diameter, a tangent to it, Az, from A is drawn, limited by the perpendicular radius, and finally AI is laid off equal to Az.

The point, I, having been thus found by either construction, draw IC parallel to Ay to the intersection, C, with RD. AC is the plane of rupture. On laying off $IL = IC$, and dropping the perpendicular, CH, from C on AD, the earth pressure, E, on AF is given by $\frac{1}{2}\ CI\ .\ CH\ .\ e$, where e is the weight of a cubic unit of the earth; otherwise, the value of E is given by e times the area of the shaded triangle, ICL. If the dimensions are in feet, and e is in pounds per cubic foot, the thrust, E, will be given in pounds.

In Figs. 2 and 3, the retaining boards, AB, are vertical, and BO is drawn, making the angle, $\phi + \phi'$, with the vertical, AB. The upper surface of the earth is BD, and the constructions for locating I and C are the same as for Fig. 1. AC, in all the figures, represents the plane of rupture.* In all cases, the earth thrust found as above is supposed to make the angle, ϕ' (as shown), with the normal to the inner wall surface.

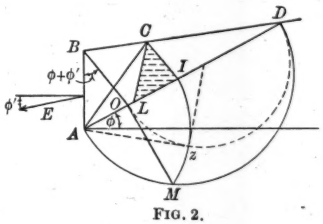

FIG. 2.

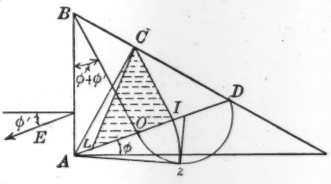

FIG. 3.

In the Rankine theory, pertaining, say, to Fig. 2, the earth thrust on a vertical plane, AB, is always taken as acting parallel to the top slope. This is true for the pressure on a vertical plane in the interior of a mass of earth of indefinite extent, but it is not true generally for the pressure against a retaining wall. Thus, when BD, Fig. 2, is horizontal, Rankine's thrust on AB would be taken as horizontal, which entirely ignores the friction of the earth on the wall. The two theories agree when $\phi' = \phi$ and BD slopes at the angle of repose, in which case, as BC is parallel to AI, there is no intersection, D. It is a limiting case in which, to compute the thrust, CIL can be laid off from any point in BD, on drawing CI parallel to BO, etc. As BD approaches the natural slope, the point, D, recedes indefinitely to

*The writer refers to his "Retaining Walls," Van Nostrand's Science Series, No. 3, for the demonstrations pertaining to the above constructions, and to the derivations of formulas.

the right, and it is seen that the plane of rupture, AC, approaches indefinitely the line, AD, or the natural slope. This limiting case, on account of the excessive thrust corresponding, will be examined more carefully in the sequel.

If h = the height of the wall, AB, in feet, and e = the weight of a cubic foot of earth, in pounds, then when $\phi' = \phi$, and the surface BD, Fig. 2, slopes at the angle of repose, the earth thrust, in pounds, is given by the equation:

$$E = \frac{1}{2} e h^2 \cos. \phi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

If, however, ϕ' is not equal to ϕ, then E is directed at the angle, ϕ', to the normal to the wall, and the thrust is:

$$E = \frac{1}{2} e h^2 \frac{\cos.^2 \phi}{\cos. \phi'} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The foregoing constructions, and the corresponding equations, are all derived from the theory of the sliding prism. The wedge, BAC, Figs. 2 and 3, is treated as an invariable solid, tending to slide down the two faces, AB and AC, at once, thus developing the full friction that can be exerted on these faces. In the case of actual rotation of the board, AB, it is found by experiment that each particle of earth in the prism, BAC, moves parallel to AC, each layer parallel to AC moving over the layer just beneath it.

A similar motion is observed if the board, AB, is moved horizontally to the left. However, in the first case (of rotation) the particles at A do not move at all, whereas in the second (of sliding motion) the particles about A move, rubbing over the floor, which thus resists the motion by friction. A thrust, thus recorded by springs or other device, in the case where the wall moves horizontally, would give an undervaluation at the lower part of AB and consequently the computed center of pressure on AB would be too high. On that account, only the experiments on rotating boards will be considered in this paper.

The theory of the sliding wedge, however, is justified, because no motion of either kind is actually supposed. The wedge, BAC, is supposed to be just on the point of motion, it being in equilibrium under the action of its weight, the normal components of the reactions of the wall, and the plane, AC, and all the friction that can be exerted along AB and AC. These forces remain the same, whatever incipient motion

is supposed. The hypothesis of a plane surface of rupture, however, is not exactly realized, experiment showing that the earth breaks along a slightly curved surface convex to the moving mass. For the sake of simplicity, the theory neglects the cohesion acting, not only along AC, but possibly to a small extent along AB. This additional force will be included in certain investigations to be given later.

These preliminary observations having been disposed of, the results of certain experiments on retaining walls at the limit of stability will now be given.

Figs. 4, 5, 6, and 7 refer to vertical rectangular walls backed by sand, except in the case of Fig. 5, where the filling was macadam screenings. The surface of the filling was horizontal in each case.

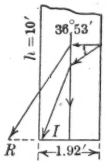

FIG. 4.

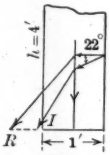

FIG. 5.

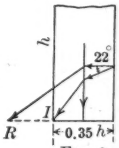

FIG. 6.

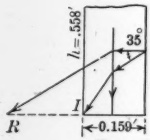

FIG. 7.

To give briefly in detail the quantities pertaining to each wall, the following symbols will be used:

h = height of wall, in feet;
t = thickness of wall, in feet;
e = weight of filling, per cubic foot;
w = weight of wall, per cubic foot;
ϕ = angle of repose of filling;
ϕ' = angle of friction of filling on wall;
q = distance from center of pressure on the plane of the base to the outer toe, divided by t, using the theory that rationally includes the whole of the wall friction;
q_0 = the same, according to the Rankine theory.

q and q_0 are positive when the resultant on the base strikes within the base, otherwise they are negative.

Fig. 4 represents Lieut. Hope's wall of bricks laid in wet sand: $h = 10$, $t = 1.92$, $e = 95.5$, $w = 100$, $\phi = \phi' = 36° 53'$. It was 20 ft. long, and was backed by earth level with its top. $q = + 0.04$, $q_0 = - 0.58$. The overhang, at the moment of failure, was probably 4 in. Including this, $q = - 0.02$.

Fig. 5 shows Baker's wall of pitch-pine blocks, backed by macadam screenings, the level surface of which was 0.25 ft. below the top of the wall; $h = 4$, $t = 1$, $e = 101$, $w = 46$, $\phi = 39° 48'$, $\phi' = 22°$, the assumed angle of friction of timber on stone, $q = -0.06$, $q_0 = -0.55$.

Trautwine's experimental wall is shown in Fig. 6. Only the ratio of base to height, 0.35, was given by the author, but J. C. Trautwine, Jr., Assoc. Am. Soc. C. E., assures the writer that the walls were probably 6 in. in height, though certain notes refer to walls varying from about 4 to 9 in. $e = 89$, $w = 28$, $\phi = 33° 42'$, ϕ' (assumed) $= 22°$, $q = -0.03$, $q_0 = -0.75$.

The wall of Curie, Fig. 7, was of wood coated on the back by sand, so that $\phi = \phi' = 35°$. Also, $h = 0.558$ ft., $t = 0.159$ ft., $\frac{e}{w} = 3.29$, $q = 0.02$, $q_0 = -1.32$.

These walls were all at the limit of stability, and the first two are of appreciable height, 10 ft. and 4 ft., respectively.

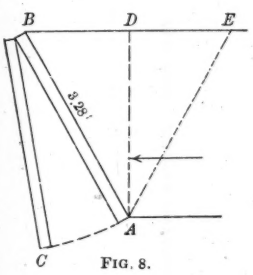

FIG. 8.

The figures show that the theory, including the whole of the wall friction, agrees fairly well with experiment, but that the Rankine theory does not thus agree. In both theories, the thrust, E, is supposed to act at one-third of the height from the base of the wall to the surface of the filling; but, in the Rankine theory, this thrust is assumed to act horizontally, whereas, in the other theory, it is supposed to act in a direction making the angle, ϕ', below the normal to the wall.

On combining the thrusts with the weight of the wall, as usual, the resultant strikes the base produced, at R in the first case (Rankine theory), but at I in the second case. Figs. 4 to 7 present a striking object lesson as to the inaccuracy of the Rankine method of treating experimental retaining walls.

In the next experiments, however, referring to a retaining structure consisting of two boards, hinged at the top, Fig. 8, and backed by sand level at the top, the Rankine theory is applicable when the board, AB, is placed either at or below the plane of rupture, on the left of AD. The thrust on AD is then assumed to act horizontally, at $\frac{1}{3}$ AD above A, and is combined with the weight of the sand, DAB, to find the

resultant on the board. If the board is at the plane of rupture, this resultant will make the angle ϕ below the normal to AB; hence, if one assumes a less thrust on AD, especially if inclined downward, the new resultant on AB will make an angle greater than ϕ with the normal to AB, which is inconsistent with stability.* The same reasoning applies when AB lies below the plane of rupture.†

The retaining board, 1 m. square, was coated with sand, so that $\phi = \phi' = 35°$ for damp sand. Hence, for a horizontal thrust on AD, the plane of rupture (which bisects the angle between the vertical and the natural slope) makes an angle of 27° 30′ with the vertical. The board, AB, was set at this angle to the vertical, sand was filled in level with the top, and it was found that the structure was at the limit of stability when $AC = 0.45$ m. In the meantime, however, the sand had dried out, so that ϕ was 33° 30′; hence, strictly, the construction of Fig. 1 (for earth level with top of wall) applies; but, as the results can only differ inappreciably, the thrust on AD, acting horizontally, was computed for $\phi = 33° 30'$ and combined with the weight of sand, BAD, and the weight of structure, both acting through their centers of gravity, to find the resultant on the base, AC. It was found to cut it 0.11 of its width from the outer toe, C; therefore $q = 0.11$.

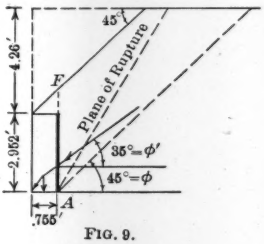

FIG. 9.

In the next experiment, the angle, BAD, was 55°, $AC = 0.548$ m. and $\phi = 33° 30'$. Pursuing the same method, it is found that $q = 0.02$, or the resultant on the base passes practically through C. The third experiment was on a smaller retaining board. Here $AB = 0.2$ m., $BAD = 55°$, $\phi = \phi' = 35°$, and $q = 0.06$.

In Fig. 9 is shown a surcharged wall of Curie's, just at the limit of stability, having $h = 2.952$ ft., $t = 0.755$ ft. and the level upper surface of the surcharge being 4.26 ft. above the top of the wall. The surcharge extended over the wall at the angle, $\phi = 45°$, corresponding to damp sand. Experiment gave $\phi' = 35°$. The wall was of brick in Portland cement. The ratio, $\frac{e}{w} = 0.62$. It was found, using the

* A full discussion may be found in the writer's "Retaining Walls."

† The experiments pertaining to Figs. 7, 8, and 9 are due to Curie. See Curie's "Poussée des Terres" and "Trois Notes," Gauthier-Villars, Paris. They are of especial interest in that they were undertaken to attempt to overthrow the theory advocated above.

construction of Fig. 1, that taking the thrust, E, as acting 1.24 ft. above the base, or at one-third of the height of the surface, AF, that $q = +\ 0.03$; and further, that if E acts 1.303 ft. above the base, the resultant on the base passes exactly through the outer toe of the wall.

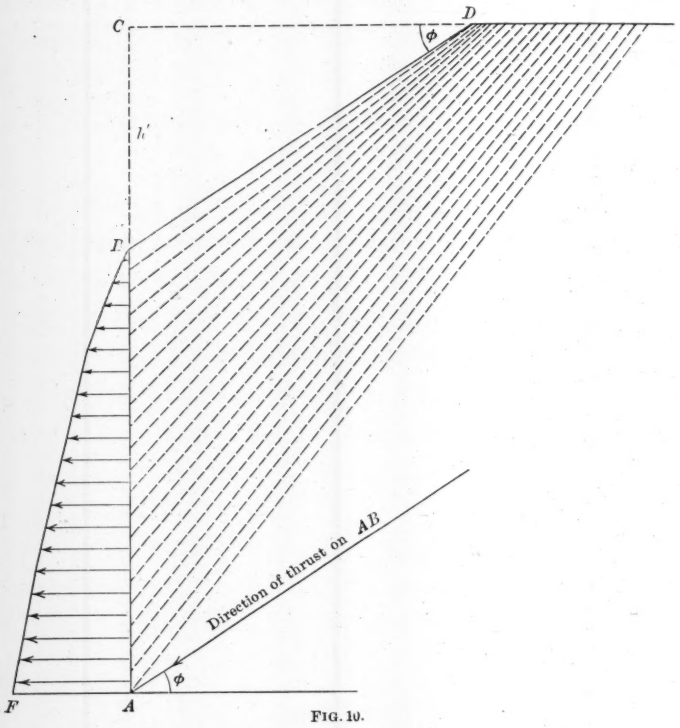

FIG. 10.

As the true position of the center of pressure on a surcharged wall has never been ascertained, as far as the writer knows, he has made a number of constructions, after the method illustrated in Fig. 1, in order to find it.

In place of making the construction for the special case above, it was thought that the results would be more generally useful if the natural slope was taken with a base of 3 and a rise of 2, and $\phi' = \phi$, therefore $\phi = \phi' = 33°\ 41'$. The wall, AB, Fig. 10, was taken vertical and 20 ft. high. The surcharge sloped from B at the angle

of repose to a point, D, 10 ft. above B, from which point the surface of the earth was horizontal. The face of the wall, AB, was divided into twenty equal parts, 1 ft. each; and, by the construction of Fig. 1, the thrusts (inclined at the angle, ϕ, below the normal to the wall) were found for the successive heights of wall of 1, 2, 3, ... 20, ft., respectively, taking the weight of 1 cu. ft. of earth equal to unity. The successive planes of rupture are shown by the dotted lines in Fig. 10. On the original scale (2 ft. to 1 in.), the upper plane of rupture (for a height of wall = 1 ft.) was found to pass slightly to the right of D.

On subtracting successive thrusts, the thrusts on each foot of wall were obtained. These were plotted as horizontal ordinates at the center of each foot division of the wall, and the "peaks" were slightly rounded off, as shown on the figure. Since, with all care, mistakes amounting to 1% of the total thrusts can easily be made, it was proper to adjust the results in this manner to give the most probable unit pressures on the successive divisions of the wall. The centers of pressure, for heights of the wall varying from 5 to 20 ft., were easily obtained by taking moments about some convenient point; the results are given in Table 1.

Call h the height of wall, measured from B downward, and $h' = BC$, the height of surcharge above the top of the wall; also, let c = the ratio of the distance from the foot of the wall considered to the center of pressure, to the height of the wall. The values of c, for various ratios, $\frac{h'}{h}$, are given in Table 1.

TABLE 1.

$\frac{h'}{h}$	c	$\frac{h'}{h}$	c	$\frac{h'}{h}$	c	$\frac{h'}{h}$	c
∞	0.333	1.50	0.356	1.00	0.364	.....	.....
.....	.....	1.25	0.360	0.75	0.364	0.00	0.333
2.00	0.353	1.11	0.362	0.50	0.364		

It is seen, as $\frac{h'}{h}$ diminishes, that c increases, until for $\frac{h'}{h} = 1$, the maximum value for c, 0.364, is attained and remains the same up to $\frac{h'}{h} = 0.50$, after which it probably diminishes, because, for $\frac{h'}{h} = 0$, $c = \frac{1}{3}$.

When some other flatter slope is given to BD, doubtless these values of c will be altered, but, for the case supposed, they should prove serviceable in practice.

Although the earth thrusts on successive portions of AB are really inclined at $\phi°$ below the normal to AB, they are laid off here at right angles to it, so that the area, ABF, is equal to the total thrust on AB. If the unit pressures varied as the ordinates to the straight line, BF, as for a uniformly sloping earth surface, then, as is well known, $c = \frac{1}{3}$. The area to the left of BF gives the excess thrust which causes c to exceed $\frac{1}{3}$.

Making use of the results of the table as approximately applicable in the foregoing example (Fig. 9), and taking the center of pressure on AF as $0.364\,AF$ above the base, the resultant there is found to pass 0.02 outside of the base, therefore $q = -0.02$. This experiment on a surcharged wall, of the kind shown, is particularly valuable as being the only one of which any account has been given, as far as the writer knows.

Recurring once more to Fig. 10, it may be recalled that some authors have assumed the unit pressures on AB to vary as the ordinates to a trapezoid, so that the unit pressure at B was not zero (as it should be), but an amount assumed somewhat arbitrarily. In particular, Scheffler derived in this way $c = 0.4$ as an upper practical limit, and used it in making tables for use in practice.

A remark must now be added (relative to all the experimental walls previously mentioned, except Trautwine's), that the friction of the backing on the sides of the box in which the sand was contained has been uniformly neglected. Where the wall is long, this can have little influence, but where the length is not much greater than the height, as in the experiments, this side friction becomes appreciable.

Darwin, as well as Leygue, endeavored to estimate the amount the full thrust (with no side friction) was reduced, by experimenting with sand behind a retaining board, or wall, enclosed in a box as usual, when a partition board was placed perpendicular to the wall and centrally in the mass, and comparing results with those found when the partition board was omitted. Leygue thus found, for walls having a length of twice the height, that the true or full thrust was diminished about 5% from the side friction, for level-topped earth, and as much as 15% for the surface sloping at the angle of repose.

If this is true, then the experimental walls just considered would have to be thicker to withstand the actual thrust; or, to put it another way, for the given thickness, the theoretical thrust, including the side friction, would have to be made (as a rough average) about 5% less for the level-topped earth and (roughly) 15% less for the earth sloping at the angle of repose. From the figures it is seen that this will modify the results but slightly, not enough to alter the general conclusion that the theory advocated (including the wall friction) is practically sustained by the experiments, and that the Rankine theory is not thus sustained.

Trautwine's wall consisted of a central portion of uniform height, from which it tapered to the ends, the upper surface being at the angle of repose for the tapered ends. In this case no side friction was developed. The results agree in a general way with the others.

In the many experiments on high grain bins, the enormous influence of the friction of the grain against the vertical walls or sides of the bin has been observed. In fact, the greater part of the weight of grain, even when running out, is sustained by the walls through this side friction. This furnishes another argument for including wall friction in retaining-wall design.

In connection with this subject, it may be observed that many experiments, made to determine the actual lateral pressure of sand or its internal friction angle, are inconclusive, because an unknown part of the vertical pressure applied to the sand in the vertical cylinder or box was sustained by the sides of the cylinder or box. The ratio of lateral to vertical pressures, or the friction angle, cannot be precisely found until the proportion of the load sustained by the sides of the containing vessel has been ascertained experimentally. The writer is of the opinion that the best experiments to aid in the design of retaining walls are those relating to the rotation of retaining walls or boards. The few given herein are the best recorded, though some of them were on models which were too small. In fact, for the small models of Leygue and others, the effect of cohesion is so pronounced that some of the results are very misleading.

As the experiments by Leygue* were very extensive, and evidently made with great care, they will be considered carefully in what follows.

* All the experiments of Leygue referred to in what follows may be found in *Annales des Ponts et Chaussées*, November, 1885.

As preliminary to the discussion, however, it is well to give the essentials of Leygue's experimental proof that cohesion and friction exist at the same time. A box without a bottom, about 4 in. square in cross-section and 4 in. high, was made into a little carriage by the addition of four wheels. The latter ran on the sides of a trough filled with sand which the bottom of the box nearly touched. The box was partly filled with sand, and the trough and box were then inclined at the angle at which motion of the box just began, the sand in the box resting on the sand in the trough, developing friction or cohesion or both, just before motion began. Only friction was exerted after motion began. The solution involves the theory of the inclined plane, but, to explain the principles of the method, it will suffice to suppose the trough and the sand in it to be horizontal, and that the bottomless box filled with sand is just on the point of moving, due to a horizontal force applied to it. The weight of the box and a part of the weight of the sand in it held up by the friction of the sides, is directly supported by the wheels resting on the sides of the trough; so that only a fraction of the weight, W, of the sand in the box is supported directly by the sand in the trough. Call this amount $n\ W$. Then, for equilibrium, calling P the horizontal force, less the resistance of the carriage wheels, we have,

$$P = A\ k + n\ W\ f,$$

where A = the area of the cross-section of the box,
k = the force of cohesion per unit of area,
and f = the coefficient of internal friction of the sand.*

The value of n was found by weighing: For the dry sand it varied from 0.79 to 0.65, for heights of the sand in the box varying from 1.2 to 3.5 in. For the damp sand and fresh earth (slightly moistened and slightly rammed) which can stand with a vertical face for the height of the box, the filling was loosened by many blows on the box, and n was taken equal to 1.

Three suppositions were made: (1) that both cohesion and friction acted at the same time before motion; (2) that friction alone acted ($k = 0$); (3) that cohesion alone acted ($f = 0$).

* We can suppose, here, the horizontal force to be the pull of a cord extending horizontally from the box and passing over a fixed pulley, and that at the free end of the cord a weight is applied. The friction of the pulley and carriage wheels could be found experimentally and allowed for, so that some fraction of this weight would equal P.

The results for various heights of sand in the box are given in Table 2.

TABLE 2.

	(1)		(2)	(3)
	k	f	f	k
Dry sand	7	0.70	0.80 to 0.96	26 to 56
Wet sand	40	0.85	1.20 " 1.90	73 " 133
Very wet sand	31	1.70	2.00 " 2.40	107 " 226
Fresh earth	90	1.63	2.60 " 4.40	150 " 242

The values of k are given in kilogrammes per square meter. It is seen that suppositions (2) and (3) give discordant results, whereas (1), for each kind of filling, gave identical values of k and of f for various heights; hence it may fairly be concluded that, before motion, cohesion and friction both acted at the same time. As to the high values found for k, for the coherent fresh earth, Leygue states that Collin found, by an independent method, for clayey earth and clay of little consistency, $k = 113$ and $k = 193$, respectively. As a further verification of the values of k and f given in (1), it is found that, on using them in the formula for computing the height at which the wet sand or earth will stand vertically, the results agree with experiments.

The values of k, in pounds per square foot, given in Column (1), with the values of ϕ corresponding to the f given, are as follows:

Dry sand, $k = 1.47$, $\phi = 35°$
Wet sand, $k = 8.28$, $\phi = 40° 22'$
Very wet sand, $k = 6.36$, $\phi = 59° 30'$
Damp fresh earth, $k = 18.45$, $\phi = 58° 28'$

It is possible that the method used by Leygue may prove of service to experimenters in obtaining more accurately than hitherto the coefficient of internal friction. Increasing pressures could be obtained by adding weights on top of the sand in the box; but, unless the total weight sustained by friction along the sides of the box is determined carefully for each weight used, the results can have but little value. Further, for coherent earths, the method of Leygue is open to objections.

Admitting the hypothesis that cohesion and friction act at the same time, a general graphical method* will now be given to find the thrust against the inner face, AB, of a retaining wall or board, Fig. 11, caused by the earth, $AB\ b_6\ H$, tending to slide down some plane of rupture, $A\ b_1$, $A\ b_2$, ..., the resistance along this plane being due both to friction and cohesion.

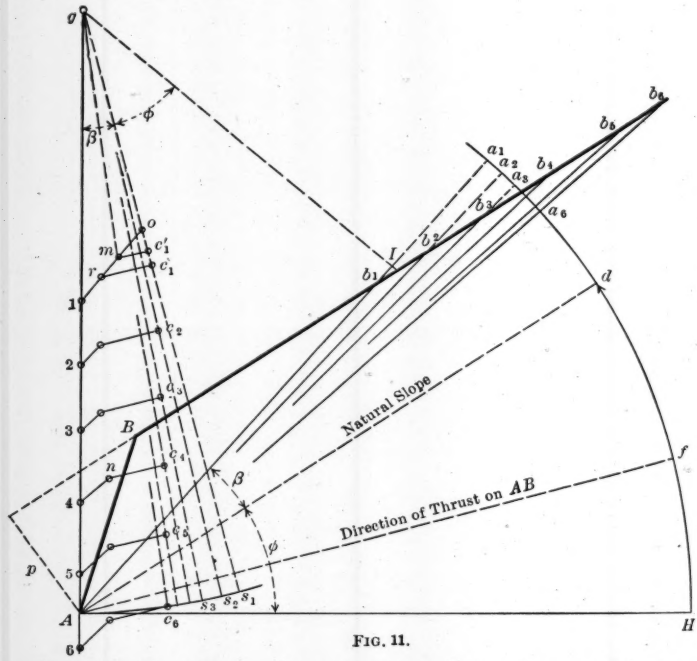

FIG. 11.

Suppose $A\ b_1$ to be the plane of rupture, and call the weight of the prism of rupture, $AB\ b_1$, for a thickness of one unit, W. The weight of the prism causes the tendency to slide along the planes, $A\ b_1$ and AB. This tendency is resisted by the reactions of the wall, AB, and the plane, $A\ b_1$. The reaction of the wall consists of the normal component, E_1, acting to the right, and the friction resistance, $E_1 \tan. \phi'$, acting up. The resultant of these two forces, E, which is equal and opposed to the earth thrust on AB, thus makes the angle, ϕ',

* This method is an extension of that given by Professor H. T. Eddy in his treatment of earth thrust, in "Researches in Graphical Statics."

with the normal to the wall. Its direction is given by $A\,f$ in Fig. 11. The reaction of $A\,b_1$ is made up of the cohesion, C, acting up along $A\,b_1$, the normal component, N, acting up, and the friction, N tan. ϕ, acting up along $A\,b_1$. The two forces, N and N tan. ϕ, when combined, give a resultant, S, making an angle ϕ with the normal, $g\,I$, to $A\,b_1$. Hence, if the angle, $I\,g\,s_1 = \phi$, then $g\,s_1$ gives the direction of the resultant, S.

The prism, $AB\,b_1\,A$, is thus in equilibrium under its own weight, W, the cohesive force, C, acting up along $A\,b_1$, the reaction, E, of AB, acting to the right, and the force, S, acting up. On drawing, to the scale of force, g 1 vertical and equal to W; then 1 r parallel to $A\,b_1$ and equal to C; then $r\,c_1$ parallel to $A\,f$ to the intersection with $g\,s_1$, the sides of the closed polygon, g 1 $r\,c_1\,g$, in order, will represent the four forces, W, C, E, and S, in equilibrium.

A similar investigation pertains to any other supposed prism of rupture. To find the true one, a number of trial planes of rupture, $A\,b_1$. $A\,b_2$, ..., are assumed, and each is treated in turn as a true one (though there can be only one true one). As seen above, the resultant of the normal reaction and friction on any trial plane of rupture must be inclined below the normal to the plane at the angle, ϕ. To lay off the directions of these resultants, from any convenient point, g, say, in the vertical through A, as a center, describe an arc, $A\,s_1$, with a convenient radius, $g\,A$. With the same radius and A as a center, describe the arc, $H\,f\,d\,a_1$, cutting the trial planes (produced if necessary) at a_1, a_2, ..., a_6. Let d be the point where the line of natural slope from A cuts the arc, $H\,a_1$. On laying off the chords, $A\,s_1$, $A\,s_2$, ..., equal to the chords, $d\,a_1$, $d\,a_2$, ..., respectively, it will follow that $g\,s_1$, $g\,s_2$, ..., will make angles, ϕ, below the normals to the planes, $A\,a_1$, $A\,a_2$, ..., respectively. To prove this, take any trial plane, as $A\,b_1$, which makes the angle, β, with $A\,d$, and drop a perpendicular, $g\,I$, from g on $A\,b_1$ (produced if necessary); then, because the sides of the angles are perpendicular, $A\,g\,I = H\,A\,a_1 = \phi + \beta$, and if $A\,g\,s_1 = \beta$, it follows that $I\,g\,s_1 = \phi$, as was to be proved. Hence the chord, $A\,s_1$ = the chord, $d\,a_1$, $A\,s_2 = da_2$, etc., as stated.

The weights, in pounds, of the prisms, $A\,B\,b_1$, $A\,B\,b_2$, ..., are, $\frac{1}{2}\,ep\,.\,B\,b_1$, $\frac{1}{2}\,ep\,.\,B\,b_2$, ..., respectively, where p is the length of the perpendicular from A upon $B\,b_1$ (produced if necessary), the foot

being the unit of length and e being the weight, in pounds, of 1 cu. ft. of earth. The prisms are supposed to be 1 ft. in length perpendicular to the plane of the paper.

These weights are now laid off to the scale of force, vertically downward from g, to points 1, 2, 3, ..., and from these points, lines are drawn parallel to $A\,b_1$, $A\,b_2$, $A\,b_3$, ..., respectively, of lengths equal to $k\,.\,A\,b_1$, $k\,.\,A\,b_2$, ..., to represent the forces of cohesion, acting upward along $A\,b_1$, $A\,b_2$, ..., where k = the force of cohesion, in pounds per square foot. From the extremities of these lines, lines are drawn parallel to the direction of the earth thrust on AB (inclined at the angle, ϕ', below the normal to AB), to the intersections, c_1, c_2, c_3, ..., with $g\,s_1$, $g\,s_2$, $g\,s_3$, ..., respectively. With dividers, it is found, for this figure, that $n\,c_4$ is the longest of these lines; whence $n\,c_4$, to the scale of force, measures the earth thrust against AB, in pounds. This follows, because, for any less thrust, since n is fixed, when $n\,c_4$ becomes less, c_4 falls to the left of the first position, and the new $g\,c_4$, representing the thrust on $A\,b_4$, due to the normal reaction on it and friction only, will make a greater angle than ϕ to the normal to $A\,b_4$, which is inconsistent with the laws of stability of a granular mass. In fact, if N is the normal component of the thrust on the plane, $A\,b_4$, N tan. ϕ is all the friction that can be exerted on it. The resultant of N and N tan. ϕ thus makes an angle, ϕ, with N, and this angle cannot be exceeded. The true thrust on the wall, AB, is thus the greatest of the trial thrusts, $n\,c_4$. The prism of rupture, $A\,b_4\,B$, is in equilibrium under the four forces represented by the sides of the closed polygon, $g\,4\,n\,c_4\,g$; $g\,4$, representing its weight; $4\,n$, the cohesion acting along $A\,b_4$; $n\,c_4$, the reaction of AB (opposed and equal to the earth thrust); and $c_4\,g$ the reaction of the plane, $A\,b_4$, due to the normal component and friction on it only. The full reaction of the plane can be found by combining the forces, given in magnitude and direction by $4\,n$ and $c_4\,g$, but it is not needed.

It is to be noted that $n\,c_4$ is the least thrust for which equilibrium is possible. The other trial thrusts should now be lengthened to equal $n\,c_4$, since this is the true thrust or reaction of the wall, $A\,B$. All the new points, c_1, c_2, c_3, c_5, c_6, will now lie to the right of the old points; hence the new $g\,c_1$, $g\,c_2$, $g\,c_3$, $g\,c_5$, $g\,c_6$, will all make less angles than ϕ with the normals to the planes, $A\,b_1$, etc.; hence stability everywhere in the earth mass is assured.

The solution represented by Fig. 11 is general, and applies whether AB is inclined to the right or left of the vertical through A or coincides with it, and whether the earth surface $B\,b_6$ is horizontal or inclined above or below the horizontal. It can likewise be easily adapted to the case shown in Fig. 1.* The construction of Fig. 11 has been used in evaluating the thrust and determining (approximately) the plane of rupture in the experiments (recorded below) of Leygue on retaining boards, AB, that could be rotated about A, and thus placed at any inclination to the vertical. In all the experiments, the vertical height of AB was 0.656 ft.; the length of the board was 1.3 ft. The value of the moment of the earth thrust about A was found by use of suitable apparatus, corresponding to dry sand with a natural slope of 3 base to 2 rise, or $\phi = 33° 41'$, $\phi' = \phi$, and $c = 89$ lb. per cu. ft. By use of the partition board mentioned previously, the side friction of the sand on the glass sides of the box containing it was estimated, and the moments corrected, so as to give the true moment when there is no side friction. The notation used to express results is partly given in Fig. 12, for the general case where,

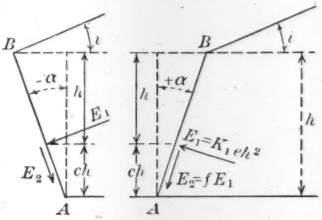

FIG. 12.

h = vertical height of the board, AB;

ch = vertical height to center of pressure on AB;

α = angle AB makes with the vertical, counted as positive or negative according as AB lies to the right or left of the vertical through A;

i = inclination of surface of earth to the horizontal;

$E_1 = K_1\ e\ h^2$ = normal component of thrust on AB, acting $c\ h$ feet vertically above A;

$E_2 = f\ E_1$ = tan. $\phi'\ E_1$ = component of thrust acting in the direction from B to A, f = tan. ϕ';

γ = angle plane of rupture makes with horizontal.

* To attain the greatest accuracy, in constructions like that shown in Fig. 11, the scale should be as large as possible; the arcs of circles, especially, must be drawn with a large radius, and the points, s_1, s_2, etc., determined with care. The angle, $H\,A\,f$, can be computed and laid off by aid of a table of chords. The construction in this figure corresponds to a vertical height of $A\,B = 0.656$ ft., $k = 1$, $e = 80$. The value of the component, E_1, perpendicular to $A\,B$, is now to be found, by drawing lines from n and c_4, perpendicular and parallel to $A\,B$, to intersection, and measuring the component to scale. For $k = 2$, it is found that $A\,b_1$ is the plane of rupture. The line, $m\,c_1'$, through the new c_1 (c_1'), representing the thrust, is very small; but it can be easily magnified by laying off the polygon, $g\,1\,m\,c_1'$, to a scale two or three times as large, and thus the thrust can be found as accurately as before.

The resultant, E, of E_1 and E_2, evidently makes the angle, ϕ', with the normal to AB. The moment of this resultant about $A = M = E_1 c h \sec. \alpha = c K_1 \sec. \alpha . e h^3 = m e h^3$, if we put $m = c K_1 \sec. \alpha$. From the last formula, it is seen that m is the moment of the thrust about A, for $e = h = 1$; also from $E_1 = K_1 e h^2$, it follows that K_1 is the normal component of the thrust for $e = h = 1$.

When cohesion is included, c is not exactly $\frac{1}{3}$, but it is very slightly less for $k = 1$ or 2. It will be assumed at $\frac{1}{3}$, and, from the values of m given by Leygue, K_1 will be derived from the formula above,

$$K_1 = 3 m \cos. \alpha.$$

Thus, for the case represented by Fig. 11, tan. $\alpha = \frac{1}{3}$, therefore $\alpha = 18° 26'$, cos. $\alpha = 0.949$; tan. $i = \frac{2}{3}$. Experiment gave $m = 0.032$, therefore $K_1 = 3 \times 0.032 \times 0.949 = 0.091$.

Neglecting cohesion, theory gives $K_1 = 0.182$, or twice the amount given by experiment. If, however, the construction of Fig. 11 is made for the actual height of the retaining board, $h = 0.656$ ft., $e = 80$, $k = 1$ (cohesion, in pounds per square foot), we find $E_1 = 2.75$. On substituting this in the formula, $E_1 = K_1 e h^2$, we have,

$$2.75 = 80 (0.656)^2 K_1, \text{ therefore } K_1 = 0.080.$$

By a comparison of the values, it is evident that, if the cohesion was assumed at a little less than 1 lb. per sq. ft., the theoretical and experimental values could be made to agree exactly. The case just examined exhibits the most pronounced difference between the ordinary theory (corresponding to $k = 0$) and experiment, of any shown in Table 3. Further, it will be observed, that, for an assumed cohesion of about 1 lb. per sq. ft., the theoretical and experimental values for all the cases given by Leygue very nearly agree.

The value, $e = 80$, in place of Leygue's, $e = 89$, was used, which would alter the results somewhat, but not the general conclusions. The construction of Fig. 11 will give E and its normal component, E_1, with practical accuracy, but it is not readily adaptable in finding the plane of rupture. In most of the drawings a small scale was used, in order to limit the drawing to a sheet of writing paper, hence, on both accounts, γ cannot be counted on to nearer than 1° or 2°, except for $k = 0$, when γ was found by computation, or by the construction of Fig. 1.

TABLE 3.

Tan. α.	Tan. i.	Cohesion, k, in pounds per square foot.	Angle of rupture with the horizontal, γ.		Coefficient K_1 of the normal component of the thrust $E_1 = K_1 e h^2$.	
			Theory.	Experiment.	Theory.	Experiment.
$+\frac{1}{3}$	0	0	50° 12′		0.060	
		1	51°	51° 30′	0.042	0.043
		2	52° 30′		0.026	
$+\frac{1}{3}$	$\frac{2}{3}$	0	33° 41′		0.182	
		1	44°	47°	0.084	0.091
		2	49°		0.043	
0	0	0	56° 36′		0.111	
		1	57°	56° 30′	0 093	0.090
		2	58°		0.077	
		3	58° 30′		0 062	
0	$\frac{1}{2}$	0	47° 30′		0.178	
		1	50°	51°	0.148	0.141
		2	53°		0.121	
		3	55°		0 098	
0	$\frac{2}{3}$	0	33° 41′		0.345	
		1	44°	49°	0.205	0.195
		2	46° 30′		0.150	
		3	50°		0.111	
$-\frac{1}{3}$	0	0	60° 21′		0.185	
		1	63°	61°	0.171	0.179
		2	63°		0.155	
$-\frac{1}{3}$	$\frac{2}{3}$	0	33° 41′		0.660	
		1	57°	57°	0.267	0.387
		2	50°		0.236	

The results in Table 3 are remarkable, and explain quite satisfactorily how Leygue, Darwin, and others found, by experiments on small models, results differing so much from the ordinary theory, where cohesion is neglected.

It should be remarked that the values of γ, given in Table 3 under "Experiment," are not exactly those given by Leygue in his tables, but are the averages obtained from the two sets of drawings given by him in the plates, and represent the inclinations of the chords of the really curved surfaces of rupture. His experiments with the spring apparatus

are not considered, as the results are open to doubt, because the prism of rupture, in descending, could not slide down freely, but as it advanced would rub over the floor, thus lessening the thrust there considerably.

From Table 3, the results given by experiment are seen to differ widely from the ordinary theory in which $k = 0$.

The discrepancies are largely, or almost entirely, due to the very small models used, as will be evident from the following considerations: Suppose the height, h, of the wall, AB, to be 10 times the height given in Fig. 11, or 6.56 ft.; then, as the areas of triangles such as $AB\,b_1$, etc., vary as the squares of the heights, but the lengths of sides, as $A\,b_1$, etc., vary only as the first power of the heights, the weights of the successive trial prisms of rupture will be 10^2 or 100 times as great as before, whereas the corresponding cohesive forces, acting along the planes, $A\,b_1$, etc., will be only 10 times the first values. Hence, if we use a scale of force $\frac{1}{100}$ of the former scale, the weights of the prisms, $AB\,b_1$, $AB\,b_2$, etc., will be represented, as before, by g 1, g 2, etc., but the lines representing the cohesive forces will be only $\frac{1}{10}$ of the former lengths. Thus the new 4 n, Fig. 11, will be laid off from 4 only $\frac{1}{10}$ of the length shown in the figure.

The relative decrease in the lines representing cohesive forces will be still more marked for a wall $20 \times 0.656 = 13.12$ ft. high, the weights of prisms being 400 times as great, but the cohesive forces only 20 times as great as before. It is evident from this reasoning that, for $k = 1$, the cohesive forces are practically negligible for walls, say, 10 ft. high, especially if the earth surface is level. In fact, a little examination of the original drawings showed, for walls about 6 ft. high, that the earth thrust, neglecting cohesion, was only from 1 to 5% in excess over that for $k = 1$. The smaller percentages referring to tan. $\alpha = -\frac{1}{3}$, or tan. $\alpha = 0$, while the larger percentages referred to tan. $\alpha = +\frac{1}{3}$, for earth surface horizontal or sloping at the angle of repose.

Such results should be of great service to future experimenters as proving two things: (1) that dry sand, with as small a coefficient of cohesion as possible, should be used (perhaps grain would be a more suitable material), and (2) that no experimental wall should be less than from 6 to 10 ft. high.

Even if the wall is, say, 6 ft. high, if damp clayey earth is used

as the filling, with a coefficient of adhesion, $k = 10$, then all the diagrams of forces, as in Fig. 11, will be the same as before, or similar figures, and the discrepancies noted in Table 3, will be as pronounced as ever. All the experiments on retaining boards, except some of Curie's, have been with very small models, and the results have brought the common theory under suspicion, if not into disrepute.

The writer hopes that the foregoing investigation and results may be instrumental in establishing more confidence in the theory, and in showing when cohesive forces may be practically neglected and when they must be included.

As an illustration, the results for a vertical wall 10 ft. high are presented in Table 4, taking $\phi = 33° 41'$ and $e = 80$. In the first wall, the surface of the earth was horizontal; in the second wall its slope was 1 rise to 2 base.

TABLE 4.

Tan. α.	Tan. i.	k.	γ.	K_1.
0	0	0	56°36′	0.111
		1	56°	0.110
		5	57°	0.101
		10	57°	0.096
0	1	0	47°30′	0.178
	2	1	49°	0.176
		5	49°	0.165
		10	49°	0.155

In Table 4 the results for $k = 0$ and $k = 1$ are practically the same, but K_1 for $k = 10$ is 13% less than for $k = 0$. If the value, $k = 18.5$, for fresh earth slightly damp and lightly rammed, given by Leygue above, is even approximately correct, it is seen that, for such a filling, the effect of cohesion must be included to get results at all agreeable with experience or experiment.

Recurring to the experimental retaining walls proper, Figs. 4 to 9, it is evident from the foregoing, that cohesion will affect the results inappreciably, except perhaps in the case of Figs. 6 and 7, where the height was about 0.6 ft. Assuming $k = 1$, it seems to be probable, from the results of Table 4, that the thrust should be decreased in the ratio of 93 : 111. Effecting the construction for the new thrust, it is found that the point, I, falls within the base, 0.03 of its width for Fig. 6 (Trautwine's wall), and 0.02 of its width for Fig. 7 (Curie's wall).

The theory advocated is thus practically sustained by all the experiments given above, either on retaining boards or retaining walls proper, when a coefficient of cohesion of about $k = 1$ for dry sand is used.

The method of evaluating the thrust, given in Fig. 11, is as valid when $k = 0$, or cohesion is neglected, as in the ordinary theory. The lines parallel to the thrust are now drawn directly from 1, 2, ..., to the intersection with $g\,c_1$, $g\,c_2$, ..., and the greatest one is taken for the true thrust. Although the writer expressly disclaims any great accuracy in the values of K_1 in Table 4, on account of the small scale of the drawings, nevertheless, the results by the construction for $k = 0$ and tan. $i = 0$ or $\frac{1}{2}$, were found to differ from computed values only 2, 3, 0, and 1 % for the different cases, which should give confidence in the general conclusions, at least.

The diagram, Fig. 11, with a slight modification, can be utilized to find the coefficient of cohesion, k, at which the bank of earth will stand without a retaining board. Thus, let each line, as $4\,n$, representing the cohesive force acting along its proper plane, be extended to meet the corresponding $g\,c$; any such line measured to the scale of force and then divided by the length of the plane along which it acts, will give the cohesive force, in pounds per square foot, corresponding to no thrust on AB, for the particular plane considered. The greatest of these values is evidently the value of k for which the filling will stand without a retaining board. The work can be much abbreviated by using a well-known principle, that the plane along which the unit cohesion is greatest (the plane of rupture) bisects the angle, $BA\,d$, between the surface, AB, and the line of natural slope. Suppose $A\,b_1$ to be this plane, then we have only to extend $1\,m$ to meet $g\,c_1$, at 0, measure 10 to the scale of force, and divide by the length of $A\,b_1$, to the scale of distance, to find the coefficient desired. By either method it was found that a cohesive force of 7 lb. per sq. ft. was required to sustain a mass of earth with a vertical face, $AB = 0.656$ ft. high, when $B\,b_6$ was horizontal.

It was stated, in connection with Equations (1) and (2), referring to the thrust on a vertical wall of height, h, with the earth surface sloping at the angle of repose, that this particular case would be discussed later. To show the influence of cohesion, the planes of rupture for such a wall, 2.4 ft. high, for various values of k (in pounds per square

foot), are given in Fig. 13. The values of K_1 (for $e = 80$ and $\phi = \phi' = 33° 41'$) are as follows:

$k = 0$	$K_1 = 0.345$	$k = 5$	$K_1 = 0.183$
$k = 2$	$K_1 = 0.237$	$k = 10$	$K_1 = 0.120$
$k = 3$	$K_1 = 0.215$	$k = 15$	$K_1 = 0.075$

The first value was found by computation, the others by construction. As is well known, the theoretical plane of rupture approaches indefinitely the natural slope as k approaches zero. For appreciable cohesion (and there is always some cohesion) the plane of rupture lies above the natural slope, with very materially decreasing normal components to the thrust as k increases. As the height of wall increases, the influence of cohesion diminishes. Thus, as shown above, for a wall 5 times 2.4 ft., or 12 ft. high, the weights of the prisms, ABC, etc., are 25 times the former values, but the cohesive forces, which vary directly as AC, etc., are only 5 times the first values. Hence, if the former values of k are multiplied by 5, the new diagram of forces, Fig. 11, will be similar to the old one. Thus, for the wall 12 ft. high, the plane of rupture and the value of K_1, for $k = 10$, correspond to the old values for $k = 2$, for $k = 15$, to the old values for $k = 3$. For fresh earth filling, slightly packed, it is possible that the values, $k = 10$, $k = 15$, may be reached, with a material reduction in K_1 from the values given by Equations (1) and (2). As the height of the wall increases, say to 25 or 50 ft., the influence of cohesion, in diminishing the thrust, becomes very small, and it is better to ignore it altogether. In fact, as we know very little, and that imperfectly, of the coefficients of cohesion, it is perhaps safer, at present, to use Equations (1) and (2) in all cases. It is very evident, though, that for most cases in practice, the formulas give a very appreciable excess over the true thrust, and that the true plane of rupture never coincides with the natural slope.

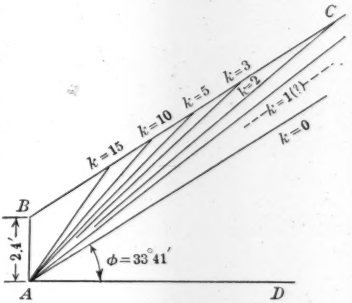

FIG. 13.

From all that precedes, it is seen that the results of experiments on small models in the past have proved to be very misleading, and that experiments on large models are desirable, and can alone give confidence. Leygue has made such experiments on retaining boards, from 1 to 2 m. (3.28 to 6.56 ft.) in height, simply to determine the surface of rupture. This is really the essential thing, for, as soon as the prism of rupture is known, the thrust is easily found. In a general way, the results agree with theory when the cohesion is neglected, though the curved surfaces of rupture were very irregular, particularly for the stone filling. The first two experiments were made with both dry and damp sand as a filling; the next six, with stones varying from 1.5 to 20 in. in diameter. In another series of five experiments, sand was used. In all the foregoing experiments, the surface of the material was horizontal. In three additional experiments, the walls were surcharged with sand as a filling. In one experiment, the wall was 6.56 ft. high and the surcharge was 3.28 ft.; in another experiment, the wall was 3.28 ft. high, and the sand, sloping from its top at the angle of repose, as in the former case, extended to 3.28 ft. above the wall, where the surface was horizontal.

Applying the construction of Fig. 1, it was found that the plane of rupture passed, say, 2° above that given by experiment in the first case and about 3° below in the second. It will be evident from the construction of Fig. 11, omitting cohesion, that trial planes of rupture differing by 2 or 3° from the true one, give nearly the same thrust. Taking the average, these experiments on large models, tend, in a general way, to sustain the theory.

In a paper by the late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., "The Actual Lateral Pressure of Earthwork,"* two experiments by Lieut. Hope and one by Col. Michon, on counterforted walls, are given. Although such walls do not admit of precise computation, on account of the unknown weight of earth carried by the counterforts, through friction caused by the thrust of the earth in a direction perpendicular to the counterforts, still the computation was made, as the conclusions are interesting. Therefore, the first vertical wall of Lieut. Hope was examined, especially as Mr. Baker, using the Rankine theory, found, for this wall, the greatest divergence between the actual and the Rankine thrust, of any retaining wall examined.

* *Minutes of Proceedings*, Inst. C. E., Vol. LXV, p. 140; reprinted in Van Nostrand's Science Series.

At the moment of failure, the wall was 12 ft. 10 in. high, the thickness of the panel was 18 in., and the counterforts were 10 ft. from center to center, projecting 27 in. from the wall, or 3 ft. 9 in. from the face, as inferred from the next example. As it is stated that the wall had the same volume as the 10-ft. wall previously examined in this paper (Fig. 4), the counterforts must have been 2 ft. thick. Assuming these dimensions, and using the values given; tan. $\theta = \frac{3}{4}$, or $\theta = 36° 52'$ (say $= \phi'$), $e = 95.5$ lb. $=$ weight of a cubic foot of earth, and $w = 100$ lb. $=$ weight of a cubic foot of masonry, we first compute $E_1 = 1\,496$ lb., the normal component of the earth thrust on a length of 1 ft. of wall. The normal thrust on the panel is thus 8 E_1 and on the counterfort 2 E_1. The friction (acting vertically downward) caused by this thrust is 8 E_1 tan. θ on the panel and 2 E_1 tan. θ on the counterfort. The moment of these forces about the outer toe of the wall, totals 39 800 ft-lb. The resisting moment of 10 ft. in length of combined panel and counterfort, about the outer toe, assuming the wall to be vertical, is 29 800 ft-lb. If, to the latter, we add the moment of 17% of the weight of earth between the counterforts, supposed to be held up by the sides of the latter, the total moment exactly equals the first. However, at the moment of failure by overturning, the panels had bulged $4\frac{1}{2}$ in. and the overhang at the top was $7\frac{1}{2}$ in. Taking the moment of stability of the wall at 26 000 ft-lb. (Mr. Baker's figure), it is found that, for equilibrium, 24% of the weight of earth between the counterforts must be carried by them. When the earth was 8 ft. high, a heavy rain was recorded, so that, doubtless, some appreciable cohesion was exerted, though necessarily omitted in the computation.

The experimental wall of Col. Michon was 40 ft. high, with very deep counterforts, only 5 ft. from center to center. The very heavy and wet filling between the counterforts, being treated as a part of the wall, a construction (made on the printed drawing) shows that the resultant of earth thrust and weight of wall passes through the outer toe. Doubtless the cohesion factor in this wall was large. In the paper mentioned, the details as to Gen. Burgoyne's experimental walls are given. There were four of these walls, each 20 ft. long, 20 ft. high, and with a mean thickness of 3 ft. 4 in. Two of the walls were perfectly stable, as in fact theory indicates for all four walls if they were monolithic. The other two walls fell, one bursting out

at 5 ft. 6 in. from the base, and the other (a vertical wall), breaking across, as it were, at about one-fourth of its height. As these walls consisted of rough granite blocks laid dry, it is highly probable that the breaks were due to sliding, owing to the imperfect construction; besides, "the filling was of loose earth filled in at random without ramming or other precautions during a very wet winter."

From a consideration of all the observations and experiments (some of them unintentional), Mr. Baker concludes that the theoretical thrust is often double the actual lateral pressure. He used the old theory, which neglects both cohesion and wall friction. If he had included them, the resulting theory would not have been so deficient "in the most vital elements existent in fact" as he charges against the "textbook" theory.

However, the writer must be clearly understood as not recommending that cohesive forces be considered in designing a retaining wall backed by a granular material, such as fresh earth, sand, gravel, or ballast. It has been the main object of this paper to show that, although cohesive forces must be included in interpreting properly the results on small models and many retaining walls, yet, for walls more than 6 or 10 ft. in height, backed with dry fresh material, not consolidated, the cohesive forces can be practically neglected in design. Hence, experimenters are strongly advised to leave small models severely alone and confine their experiments to walls from 6 to 10 ft. high, backed by a truly granular material, such as dry sand, coal, grain, gravel, or ballast, where the cohesive forces will not affect the results materially. Further, it is evident that walls of brick in wet sand, or walls of granite blocks, etc., laid dry, are very imperfect walls. The overhang, just before falling, is large, and the base is often imperfect. For precise measurements, a light but strong timber wall on a firm foundation, seems to be best; and the triangular frame of Fig. 8 seems to meet the required conditions very well, especially if the framing is an open one, with a retaining board only on one leg. The base thus becomes wider, and the overhang less, than with any rectangular wall.

When the design of a wall to sustain the pressure of consolidated earth is in question, even if a perfect mathematical theory existed, it would still prove of little or no practical value, because the coefficients of friction and cohesion are unknown. The coefficient of friction at the surface can be easily found, but it is a difficult matter to find the

coefficient of cohesion, which doubtless varies greatly throughout the mass.

Mr. W. Airy, in his discussion of Mr. Baker's paper, states that he found the tensile strength of a block of ordinary brick clay to be 168 and of a certain shaley clay 800 lb. per sq. ft., the coefficients of friction for the two materials being 1.15 and 0.36, respectively. Cohesive resistance is more analogous to shear, but such figures indicate the wide variations to be expected, particularly in k, the coefficient of cohesion. If this coefficient is to be guessed at, in order to substitute it in the supposed perfect formula, then it is plainly better to guess at the thickness of the wall in the first instance.

As an illustration, consider the well-known equation:*

$$h = \frac{4\,k}{e}\,\frac{1 + \text{sin. } \phi}{\text{cos. } \phi} = \frac{4\,k}{e}\left(f + \sqrt{1 + f^2}\right)$$

which gives the height, h, of vertical trench that will stand without any sheeting.

In this equation,

k = the cohesive or shearing resistance, in pounds per square foot;
e = the weight of a cubic foot of earth, in pounds;
f = tan. ϕ;
ϕ = the inclination of the natural slope; and
h = the height of the unsupported bank, in feet.

Thus, if $f = 0.7$, whence $\phi = 35°$, the equation reduces to

$$h = 7.68\,\frac{k}{e}$$

For, $e = 100$, $k = 100$, $h = 7.68$ ft.,
$e = 100$, $k = 200$, $h = 15.36$ ft.,
$e = 100$, $k = 300$, $h = 23.04$ ft.

As certain trenches with vertical sides have been observed to stand unsupported for heights of 15 or even 25 ft., the equation would seem to indicate that cohesive or shearing resistances of about 200 to 300 lb. per sq. ft. were required to cause equilibrium. If friction is not supposed to be exerted, then $f = 0$ and $h = 4\,\frac{k}{e}$; and, for the same unsupported heights, the cohesion would be about doubled. Evi-

* In reference to this equation, see Appendix.

dently, if cohesion, which (to judge from Mr. Airy's experiments) may vary from one to several hundred pounds per square foot, has to be guessed at in order to determine h, it is plainly better to guess at h at once.

The foregoing equation cannot be regarded as giving very accurate results, mainly because a plane surface of rupture is assumed, whereas, from both theory and observation, this surface is known to be very much curved; besides, the cohesion and friction along the ends of the break have been neglected. However, the hypothesis of a plane surface of rupture, the ends being supposed to be included, gives a greater value to h than the true one, whereas, neglecting the influence of the ends, it tends in the other direction; so that the equation may not err so greatly.

In the discussion of the paper* by J. C. Meem, M. Am. Soc. C. E., E. G. Haines, M. Am. Soc. C. E., states that where breaks occur in the sides of an unsupported trench, the solid of rupture often approximates to a quarter sphere, surmounted by a half-cylinder of the same height, the radii of the sphere and cylinder being equal. In Fig. 14, let *AIBE* represent the quarter-sphere, *ABG* the half-cylinder, and *EACDB* the face of the trench. According to the observations of Mr. Haines, when the part, *ACDB*, of the side of the trench is supported by sheeting and bracing, it sometimes happens that a part of the quarter-sphere, *AIBE*, breaks out, so that the semi-cylinder above would descend but for the bracing, the thrust of which, it is supposed, induces arch action in the earth.

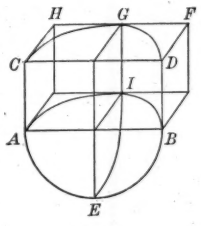

FIG. 14.

This is possible; but, if so, as the sheeting is not supposed to be carried to the bottom of the trench, there can be no vertical component in its reaction, and the thrust, B, of the braces and sheeting, acting on *ACDB*, must be horizontal; further, the earth cannot act as a series of independent arches devoid of frictional resistance between them, but must act as a whole.

Another way of explaining the phenomena is to suppose the horizontal thrust of the braces, B, on the exposed face, *ABCD*, to cause

* "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures." *Transactions*, Am. Soc. C. E., Vol. LX, p. 1. A number of important facts brought out in this paper are of vital importance to constructors.

friction at the back of the break of sufficient intensity to prevent the semi-cylinder from descending, just as a book can be held against a vertical wall by a horizontal push.

To illustrate the principle, it will suffice to replace the semi-cylinder by the circumscribing parallelopiped, AF, and suppose it to be held up by the friction on the back face, with possibly cohesion acting on the three interior vertical faces. Thus, let $AC = CH = a$, and $AB = 2\ a$; then the friction on the back face is $B\,f$, the cohesion on the three faces is $(2\,a^2 + 2\,a^2)\ k$, and the weight of earth, AF, equals $2\,a^3\ e$. Hence, as friction and cohesion always act opposite to the incipient motion, or vertically upward in this case,

$$B\,f + 4\ a^2\ k = 2\ a^3\ e.$$

Evidently, the value of B, derived from this equation, gives an extreme upper limit, which is doubtless never attained, as there is nearly always some support from the earth which has not broken out below the level of ABI.

Where the sheeting and bracing are of sufficient size, are tightly keyed up, and extend to the bottom of the trench, or where the bank is supported by a retaining wall, the earth near the bottom cannot break out, and the equation is not valid.

However, if, from any cause, such as insufficient sheeting, the break has taken place over even a part of $AIBE$, the mass, AF, above will tend to tip over at the top, giving the greatest pressure on the top braces. This appears to explain the phenomena observed by Mr. Meem and others in connection with some trenches.

With regard to tunnel linings, as is well known, the vertical pressure on the top is generally small, the great mass of earth vertically over the tunnel being largely held up by the friction of the earth (caused by the earth thrust) on its vertical sides, exactly as in the case of tall bins, where most of the weight of the grain is held up by the sides of the bin, the theory being very similar in the two cases. In consolidated earth, cohesion assists very materially in this action.

It might be inferred, from the facts of observation, that consolidated earth acts as a solid, though, of course, it differs from a solid in this: that its physical constants (cohesion, friction, etc.) vary enormously with the degree of moisture. It is likely that these constants alter with the depth, and likewise are subject to changes from shocks.

It is a question too, whether, as is the case with loosely granular materials, friction acts (before rupture) at the same time with shear or cohesion in consolidated earth. From the interesting remarks* of Mansfield Merriman, M. Am. Soc. C. E., on internal friction, it seems probable that friction and shear exist at the same time in a solid; but, to reach sound conclusions, as he states, "further studies on internal friction and on internal molecular forces are absolutely necessary."

From the present state of our knowledge with respect to the theory and physical constants pertaining to consolidated earth, it would seem that experience must largely be the guide in dealing with it. The facts are supreme—the rational theory may come later.

Similarly, for retaining walls backed by loosely aggregated, granular materials, the facts are supreme, and, on that account, they have been presented very fully in this paper; further, a theory has been found to interpret them properly. It is true that the fresh earth, from the time that it is deposited behind a retaining wall, begins to change to a consolidated earth, from the action of rains, the compression due to gravity, and the influence of those cohesive and chemical affinities which manufacture solid earths and clays out of loosely aggregated materials, and even cause the backing sometimes to shrink away from the wall intended to support it; but it is plain that the wall should be designed for the greatest thrust that can come on it at any time, and this, in the great majority of cases, will occur when the earth has been recently deposited.

The cases which have been observed where the bank has shrunk away from the wall and afterward ruptured (after saturation, perhaps) are too few in number to warrant including in a general scheme of design, even supposing that a rational theory existed for such cases. A few remarks on the theory pertaining to the design of retaining walls may not be inappropriate. From the discussion of all the experiments referred to in this paper, the conclusion may be fairly drawn that the sliding wedge theory, involving wall friction, is a practical one for granular materials of any kind subjected to a static load. In practical design, however, vibration due to a moving load has to be allowed for; also the effect of heavy rains. Both these influences tend generally to lower the coefficients of friction and add to the weight of the filling. Mr. Baker says:

* "Mechanics of Materials," Tenth Edition, p. 381.

"Granite blocks, which will start on nothing flatter than 1.4 to 1, will continue in motion on an incline of 2.2 to 1,* and, for similar reasons, earthwork will assume a flatter slope and exert a greater lateral pressure under vibration than when at rest."

Instances of slips in railway cuttings, caused by the vibration set up by passing trains, have been given by many engineers. The effect of vibration is most pronounced near the top of a retaining wall, and is evidently greater for a low wall than for a high one. All the influences cited can only be included under the factor of safety, and the writer recommends for walls from 10 to 20 ft. in height a factor of 3. This may be increased to 3.5 for walls 6 ft. high and decreased to 2.5 for walls 50 ft. high, or those with very high surcharges. In the application, the normal component of the earth thrust on the wall, E_1, will alone be multiplied by the factor, the friction, $E_1 \tan. \phi'$, exerted downward along the back of the wall, being unchanged. This allows very materially for a decrease in ϕ' due to rains and vibration, as well as for an increase in the thrust, due to ϕ becoming less.

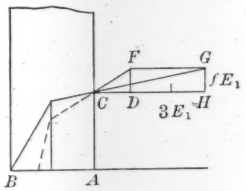

FIG. 15.

The effect is illustrated in Fig. 15, where a retaining wall is supposed to be subjected to the earth thrust, CF, making an angle ϕ' with the normal to the face, AC, of the wall. The component of CF normal to AC is $E_1 = CD$, the component acting downward along CA is represented in magnitude and direction by DF, which equals $E_1 \tan. \phi'$. Suppose the factor of safety to be 3, then CD is extended to H, making $CH = 3CD$; HG is drawn equal and parallel to DF; whence GC will represent the thrust, which, combined with the weight of the wall, acting through its center of gravity, must pass through the outer toe of the wall.

To see what thickness of a vertical rectangular wall corresponds to this factor of safety, 3, for $\phi = \phi' = 33° 41'$, or a natural slope of 3 base to 2 rise, let it be assumed that the weights per cubic foot of earth and cut-stone masonry in mortar are in the ratio of 2:3; then, for level-topped earth, a computation shows that, for the factor, 3, the base of the wall must be $0.34\,h$. If the earth slopes indefinitely at the angle of repose from the top of the back of the wall, and a factor 2.5 is used, then the thickness will be $0.49\,h$.

* Perhaps this may be accounted for by supposing cohesion between the blocks at rest, which is destroyed by the motion, when only friction acts.

For brick masonry in mortar, the specific weight of which is $\frac{5}{4}$ of that of the filling, the foregoing thickness would be changed to $0.37\,h$ and $0.52\,h$, respectively, h being equal to the height of the wall.

It must be noted especially, however, that if the original earth thrust, when combined as usual with the weight of wall, gives a resultant which passes outside of the middle third of the base of the wall as computed above, then the thickness must be increased, so that the resultant will at least pass through the outer middle-third limit. This ensures compression over the whole base and no opening of part of the joint under normal conditions. With regard to the thickness above of about one-third of the height, Mr. Baker states that hundreds of brick revetments have been built by the Royal Engineer officers, with a thickness of only $0.32\,h$ for a vertical wall. He advises, as the result of his own extensive experience, that the thickness be made one-third of the height for level-topped earth of average character, and that the wall be battered $1\frac{1}{2}$ in. to the foot. He states, further, that, under no ordinary conditions of surcharge on heavy backing is it necessary to make the thickness of a retaining wall on a solid foundation more than one-half the height. The thicknesses computed above agree fairly well with those recommended by Mr. Baker, and it would seem that a table of thicknesses computed on the above basis should correspond to safe walls under ordinary conditions.

It has been noted above that Equation (1), corresponding to a slope of indefinite extent, probably gives too great a thrust; besides, there are no embankments with such a slope. An embankment from 100 to 150 ft. high, supported by a low wall, may approximate the conditions assumed, but, before it is finished, the earth has consolidated to such an extent that the actual thrust is doubtless much less than the computed one. The truth is that, in nearly all back-filling of ordinary earth, the cohesive and chemical affinities commence their work very soon after the filling is deposited, and consolidation is gradually effected; so that, as has been stated, the actual thrust is often much less than is estimated in the design of the wall, where cohesive forces are neglected. In many old walls, as has been observed, the consolidation has gone so far that the backing has shrunk away from the wall altogether. It would be hazardous, though,

to allow for cohesion, in a wall backed by fresh earth, unless the surcharge was high and was a long time in building. Finally, it should be observed that the footing of a retaining wall should be wide, and should always be tilted at such an angle that sliding is impossible.

A glance at Figs. 4, 5, and 6, will make it apparent that the Rankine and other theories differ in their results mainly because of the assumed difference of inclination of the earth thrust. In the design of walls, however, the method proposed (Fig. 15) will approximate in results those given by the Rankine theory, where, say, the earth thrust, whether inclined or not, is multiplied by the factor of safety. The writer does not advocate the middle-third limit method in design, as it gives variable factors of safety for different types of walls. Besides, if the actual resultant on the base passes one-third of its width from the outer toe, there is no pressure at the inner toe, and the unit pressure at the outer toe is double the average. If vibration or other cause increases the thrust, the joint at the inner toe opens, and the pressure is concentrated too much near the outer toe. In the reinforced concrete wall, the earth thrust on a vertical plane through the inner toe is required. As this plane lies well within the earth mass, the thrust on it must be taken as acting parallel to the top slope, and its amount will be the same as that given by the Rankine theory.

Although it is highly desirable to have more precise experiments on large models in order to draw sure conclusions, yet, as far as the experiments go—those which have been analyzed and discussed in this paper—the following conclusions may be stated:

1.—When wall friction and cohesion are included, the sliding-wedge theory is a reliable one, when the filling is a loosely aggregated granular material, for any height of wall.

2.—For experimental walls, from 6 to 10 ft. high, and greater, backed by sand or any granular material possessing little cohesion, the influence of cohesion can be neglected in the analysis. Hence, further experiments should be made only on walls at least 6 ft., and preferably 10 ft., high.

3.—The many experiments that have been made on retaining boards less than 1 ft. high, have been analyzed by their authors on the supposition that cohesion could be neglected. This hypothesis is so far from the truth that the deductions are very misleading.

4.—As it is difficult to ascertain accurately the coefficient of cohesion, and as it varies with the amount of moisture in the material, small models should be discarded altogether in future experiments, and attention should be confined to large ones. Such walls should be made as light, and with as wide a base, as possible. A triangular frame of wood on an unyielding foundation seems to meet the conditions for precise measurements.

5.—The sliding-wedge theory, omitting cohesion but including wall friction, is a good practical one for the design of retaining walls backed by fresh earth, when a proper factor of safety is used.

As the subject of pressures on the roof and sides of a tunnel lining has received much attention of late, the writer has concluded to extend this paper, so as to give a development of a theory, based on the grain-bin theory of Janssen, but modified to include the cohesive or shearing resistances of the earth in addition to the frictional resistances.

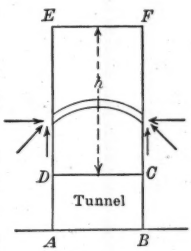

FIG. 16.

Fig. 16 is a vertical transverse section of a tunnel, *ABCD,* and the earth, *DCFE,* extending over it h feet. If this tunnel has been driven by the use of a shield or poling boards, the ground will tend to settle over it, and part of the weight of *DCFE* will be sustained by cohesion and friction (resulting from the lateral thrust) exerted along the sides, vertically upward. The earth will probably arch itself, or form a series of domes superposed one upon the other, but the external forces acting on such domes will be the same as those acting on a corresponding horizontal lamina, and the theory, given in full in the Appendix, begins with the considerations pertaining to the equilibrium of such a lamina.

If there was no settlement of the earth, *DCFE,* in relation to *DC,* then the vertical pressure per square foot on *DC* would be $w\,h$ (w being the weight of a cubic foot of the earth in pounds), but, as most of the weight of *DCFE* is carried by the sides, in case of sufficient settlement, the vertical unit pressure, V, on *DC,* will be much less than $w\,h$. Also, the lateral unit pressure, L, at the level, *DC,* will be much less where settlement occurs. From the equations for V and L, given in the Appendix, the diagrams, Figs. 17 and 18, have been constructed.

In both diagrams, the weight of the earth was taken at $w = 90$ lb. per cu. ft., and the cohesion of the earth at $c = 100$ lb. per sq. ft. In Fig. 17, $\phi = 45°$ and the curves for V and L were laid off for a width of tunnel, b, of 15 ft. and also for 30 ft. In Fig. 18, $\phi = 30°$, and curves are given for V and L, also for $b = 15$ ft. and 30 ft. for various heights, h.

It will be perceived, in both figures, that when certain heights are attained, both V and L cease to increase perceptibly, so that such values may be taken as corresponding to h indefinitely large.

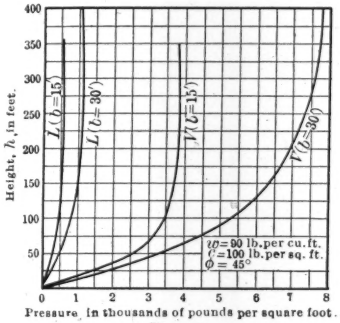

FIG. 17.

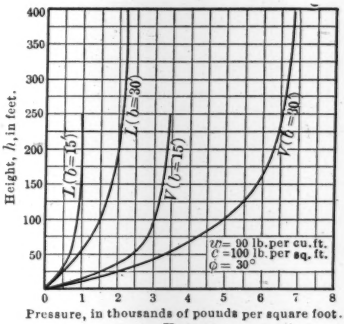

FIG. 18.

A simple way of deriving these extreme values is given in the Appendix. The values of ϕ, b and w have been taken here the same as those used by Mr. Meem, in framing his table of pressures,* which may be supposed to embody, in part, practical experience. The results found from Figs. 17 and 18 by the writer, for a depth of covering of several hundred feet, are uniformly much larger than those given by Mr. Meem. Are they too large for safety? In answering this question, it must be remembered that, of the weight of earth directly over the tunnel, all has been transferred to the sides that it was possible to transfer, for the coefficients of friction and cohesion given. We know scarcely anything of the cohesion coefficients, so that the value assumed, $c = 100$ lb. per sq. ft., may not be near the truth. Certainly it must appear plain from this discussion that the values of c and ϕ must be better known, for all kinds of earth, before reliable results can be attained. The results are submitted for discussion, in the hope that engineers will give their experience relative to the pressures

* *Transactions*, Am. Soc. C. E., Vol. LXX, p. 387.

realized in the timbering of tunnels, particularly through sand or earth not thoroughly consolidated.

The value of V, in Figs. 17 and 18, is the average vertical unit pressure at the top of the tunnel. Experiments on grain bins lead to the inference that the pressure at the middle of the roof is greater than that at the sides, but no law of variation can be stated.

The lateral unit pressure on the vertical sides of the tunnel lining at the top is given by the equation for L, or by the corresponding diagram. The variation in this lateral pressure over the sides of the tunnel cannot be easily formulated, as so much of the weight of the earth, directly over the tunnel, has been transferred by a kind of arch action to the sides. Experience would better speak here.

Table 5 gives the values of V and L for $h = 40$ ft. The figures in Columns M are taken from Mr. Meem's table, previously referred to; those for Columns C are from the diagrams, Figs. 17 and 18.

In quoting Mr. Meem's figures, the writer must not be understood as endorsing in any way his theory; but the results are of interest as embodying the conclusions of a practical engineer of large experience.

TABLE 5.

b, in feet.	ϕ.	V, IN POUNDS PER SQUARE FOOT.		L, IN POUNDS PER SQUARE FOOT.	
		M.	C.	M.	C.
15	45°	1 485	2 300	405	300
15	30°	1 035	2 100	540	600
30	45°	3 240	2 800	450	400
30	30°	2 325	2 600	450	750

If the height, h, of earth covering is 200 or 300 ft., the values given by Figs. 17 and 18 are much larger than those given in Columns M, which presumably represent Mr. Meem's pressures for any height greater than 40 ft.

In saturated earth, it has been customary, perhaps, to regard the earth as if it were gravel composed of solid spheres, like marbles, so that the water has free access in any direction. Thus, in the case of a retaining wall backed by such material, the water has full access practically to every part of the wall, and the wall is subjected to the full water pressure corresponding to its depth. It is likewise subjected to a thrust from the earth, corresponding to c and ϕ, for the saturated material, but with a weight per cubic foot equal to that of the earth in air less the buoyant effect of the water. Thus,

if a cubic foot of the porous earth, in air weighed 90 lb., and if the voids were 40%, then 1 cu. ft. of earth contains 0.6 cu. ft. of solids and the buoyant effect of the water is the weight of an equal volume of water or $0.6 \times 62.5 = 37.5$ lb. Hence, the weight per cubic foot of earth in water is $90 - 37.5 = 52.5$ lb.

Similarly, for the pressures, V and L, at the top of a tunnel, $w = 90$ must be replaced by 52.5, and c and ϕ must be found for the saturated material and these values substituted in Equations (5) and (6) of the Appendix. To these pressures must be added the corresponding water pressures for the full height of water, supposing it to have free communication everywhere, as in the case of the gravel filling. However, with sand, or earth with much fine material, the pores are more or less clogged up and there is perhaps intimate contact of a part of the earth with the roof of the tunnel, so that the water cannot get under it to produce a lifting effect, and if such intimate contact is found along any horizontal or vertical section, of the earth on either side of the section, it is plain that the buoyant effort of the water on a cubic foot of material will be much diminished.

Mr. Meem deserves great credit, not only for calling attention to this, but especially for performing certain experiments to prove it.* The experiments were on sand, and only on a small scale, but the practical conclusion drawn from them is that the water pressure transmitted through sand having 40% voids is diminished about 40% in intensity. This occurs for a depth of only a few inches of sand, and presumably the diminution would be greater for sand several feet in depth. Of course, before definite values can be stated, experiments on a large scale should be made on every kind of material usually met; but, as a numerical illustration of the application, for the diminution mentioned—which is assumed to extend through the mass—it is seen that, in the examples of the retaining wall and also the tunnel, the weight per cubic foot of the earth in water must now be taken at $90 - (0.4 \times 0.6 \times 62.5) = 75$ lb. per cu. ft.

This value replaces the w in Equations (5) and (6) from which the V and L for the top of the tunnel are found. To these values, add $0.4 \times 62.5\ h_0$, for the water pressure, where the surface of the water extends a height, h_0, above the top of the tunnel. Similarly, in the case of the retaining wall, add 0.4 of the full water thrust on the wall to that given by the earth, weighing only 75 lb. per cu. ft.

* *Transactions*, Am. Soc. C. E., Vol. LXX, pp. 365-368.

As a numerical illustration, take $b = 15$ ft., $\phi = 45°$, w in air $= 90$ lb., $h = 40$ ft., $h_0 = 60$ ft.; but we must now replace w by the weight in water, 75 lb., as found above. The values of V and L are now found, by Equations (5) and (6) (Appendix), to be 1 917 and 246 lb. per sq. ft., respectively, for the saturated earth alone. To these values add $0.4 \times 62.5 \times 60 = 1\,500$ lb. per sq. ft., water pressure, giving a total of 3 417 and 1 746 lb. per sq. ft., respectively, for the vertical and horizontal unit pressures at the top of the tunnel lining.

In connection with this subject of underground pressures, it may not be inappropriate to make some concluding remarks on the maximum vertical pressures to which culverts may be subjected.

Let Fig. 16 now represent a longitudinal vertical section along the axis of a road embankment, built over an arch culvert or box-drain, *ABCD*, the line, *CD*, passing through the summit of the arch or the top of the covering stone of the box-drain, and the lines, *AD* and *BC*, coinciding in part with the exterior sides of the abutments.

There is a horizontal thrust of the earth on the medial plane, *CDEF*, acting at right angles to the plane of the paper, which tends to distribute the weight of the central portion partly toward the sides; but, ignoring this, it is seen that, if the earth everywhere settles uniformly, the maximum pressure per square unit at the top of the culvert is $w\,h$, and the total vertical pressure on the culvert is the weight of the earth vertically above it.

If, however, the earth outside the abutment walls settles more than the walls (a case which may occur), then part of its weight, and that of the earth vertically above it, will be transferred, through friction and cohesion, along the planes, *AE* and *BF*, to the culvert, and thus the vertical pressure on the top of the culvert will be greater than in the first supposed case; but, if the reverse obtains, or if the culvert settles more than the earth outside the lines, *AD* and *BC*, or if the arch or covering stone descends in the middle relatively to the abutments, then part of the weight of the earth vertically over the culvert is transferred to the sides. For a comparatively rigid arch, the settlement is perhaps not enough to warrant us in making the maximum unit pressure less than $w\,h$. Exactly what settlement would warrant the use of the theory set forth in the Appendix it is impossible to say. If the unit pressure is taken as $w\,h$, we can rest assured that in most cases the real pressure is materially less.

APPENDIX

In the experiments of Jamieson and Pleissner on the pressures in deep grain bins*, the ratio, k, of the lateral unit pressure, L, on a vertical plane to the vertical unit pressure, V, on a horizontal plane, was found by Pleissner to vary from 0.3 to 0.5 and by Jamieson to equal 0.6, for wheat in wooden bins of various sizes.

This ratio, $k = \frac{L}{V}$, increases somewhat with the depth of the grain, but the increase is slight after a depth of from 2½ to 3 times the width or diameter of the bin is reached.

It is recognized that the proper value of k, for a particular case, can only be determined properly by experiment, but it is interesting to note that, by the theory of earth pressure of an unlimited granular mass, level at the top, the ratio of the lateral to the vertical unit pressure, at any point in the mass, is, $k' = \tan.^2\left(45° - \frac{\phi}{2}\right)$, and that this varies from 0.361 to 0.271, as ϕ, the angle of repose, varies from 28° to 35°, the values of ϕ for wheat, given in some of the experiments. Further, by reference to Jamieson's experiments on a model bin of smooth steel, 1 ft. in diameter,† filled with sand, for which $\phi = 34°$, $k' = \tan.^2\left(45° - \frac{\phi}{2}\right) = 0.283$, we find the experimental value of k to equal k' exactly for a height of sand of 2.5 ft., the value at 6 ft. and upward being 0.33.

The theory of bin pressure is utterly different from the ordinary theory of earth pressure in an unlimited granular mass; but it is seen that the latter may be of some use in furnishing a value of k when experimental values are lacking, as in the case of various kinds of earth, both granular and more or less consolidated.

An equation for L, for an unlimited mass of earth, level at the top and having a coefficient of cohesion, c, has been given by Scheffler,‡ and is as follows:

$$L = w\,h\,\tan.^2\left(45° - \frac{\phi}{2}\right) - \frac{c\cos.\,\phi}{\cos.^2\left(45° - \frac{\phi}{2}\right)} \quad \ldots\ldots\ldots(1)$$

* Given in detail in "The Design of Walls, Bins and Grain Elevators," by Milo S. Ketchum, M. Am. Soc. C. E.

† Ketchum's "Walls, Bins, and Grain Elevators," Fig. 171.

‡ "*Traité de Stabilité des Constructions*," p. 292; see also Remark at end of Appendix.

Here w = weight per cubic unit of earth,
h = depth below the level-topped, unlimited mass,
L = unit lateral pressure on a vertical plane at the depth, h.

This reduces to the usual formula when $c = 0$.

It is seen from Fig. 19, if we lay off at the depth, h, $BC = w\,h \tan.^2\left(45° - \frac{\phi}{2}\right)$, that the horizontal ordinates of the triangle, ABC, measure the values of the first term of the right member of Equation (1). The second term, $\frac{c \cos.\ \phi}{\cos.^2\left(45° - \frac{\phi}{2}\right)}$, is constant, and is represented by the horizontal ordinates of the rectangle, $ABGF$. Thus the value of L at the depth, h, is represented by $BC - BG = CG$.

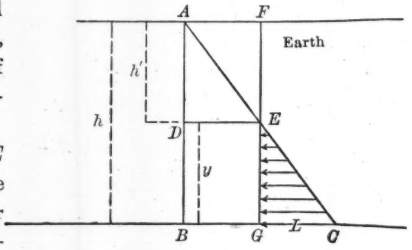

FIG. 19.

At D, $L = DE - DE = 0$; but, above D, the equation is inapplicable, for negative values of L, corresponding to tension along AD, are inadmissible; hence, above D, we must write $L = 0$.*

In Equation (1), for $h = h' = AD$, $L = 0$,

therefore, $$0 = w\,h' \tan.^2\left(45° - \frac{\phi}{2}\right) - \frac{c \cos.\ \phi}{\cos.^2\left(45° - \frac{\phi}{2}\right)} \quad \ldots\ldots\ldots (2)$$

Solving this for h',

$$h' = \frac{c}{w} \frac{2 \cos.\ \phi}{1 - \sin.\ \phi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

For given values of c, w, and ϕ, having computed h', we have, on subtracting Equation (2) from Equation (1),

$$L = w\,(h - h') \tan.^2\left(45° - \frac{\phi}{2}\right) \quad \ldots\ldots\ldots\ldots (4)$$

which is true only for $h = h'$ or $h > h'$. When $h < h'$, $L = 0$.

If we put $y = (h - h')$, the equation reduces to the ordinary form, and thus the center of pressure of the thrust on AB (or DB) acts at $\frac{1}{3}\,y$ above B, and its amount is $\frac{1}{2}\,w\,y^2 \tan.^2\left(45° - \frac{\phi}{2}\right)$.

* Scheffler has not noted this fact, and consequently some of his deductions are open to objections. His theory, involving cohesion, is the only one the writer has seen.

Call V, the vertical unit pressure at the depth h,

V', " " " " " " " " h',

therefore $V = w\,h = w\,(y + h')$,

$V' = w\,h'$;

and, putting $k = \tan.^2\left(45° - \frac{\phi}{2}\right)$, we have, from Equation (4),

$$L = w\,(h - h')\tan.^2\left(45° - \frac{\phi}{2}\right) = (V - V')\,k.$$

Next consider the case of a tunnel of width, b, and length, l, which has been driven by shield or by use of timbering, so that an appreciable settlement of the roof occurs; then the weight of the earth vertically over the tunnel is partly carried by the adjacent walls of earth, by friction and cohesion, and it would seem that such walls can be supposed to take the place of vertical grain bin walls, and that the theory of bin pressures corresponding may be made to apply. The theory that will be developed, which includes the influence of cohesion, is simply a modification of that used in developing Janssen's formula, as given by Mr. Ketchum,* and, for a ready comparison of results, his notation will be used.

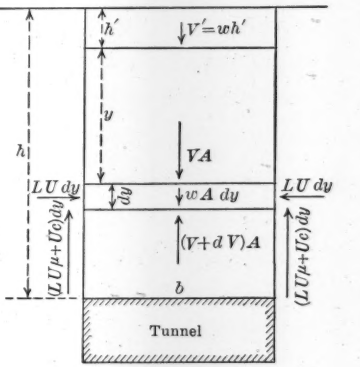

FIG. 20.

In Fig. 20, let h be the distance from the roof of the tunnel to the surface of the earth. Compute h' from Equation (3) and lay it off from the top down.

Let V = vertical unit pressure at depth, $y + h'$;

L = lateral " " " " "

w = weight of earth per cubic unit;

ϕ = angle of repose of earth;

μ = tan. ϕ = coefficient of friction of earth on earth;

$A = b\,l$ = area of horizontal section of tunnel;

$U = 2\,(b + l)$ = perimeter of section; and

c = cohesive force of earth per square unit.

* "The Design of Walls, Bins and Grain Elevators," Chapter XVI.

The foregoing equation, $L = (V - V')\ k$, will be used as a semi-empirical formula to express the relation between L and V, but now V is no longer equal to $w\ (y + h')$ but at present is unknown. As before, $V' = w\ h'$.

Properly, k should be determined by experiments, but, from lack of such experiments, it will be computed from the formula above,

$$k = \tan.^2 \left(45° - \frac{\phi}{2}\right).$$

Consider now the conditions of equilibrium of a horizontal slice of earth of depth, dy, the weight of which is $A\ w\ dy$.

The top surface, at the depth, $y + h'$, is acted on by the force, VA, acting downward, and the bottom surface by the force, $(V + d\ V)\ A$, acting upward. The total lateral force acting on the area, $U\ d\ y$, is $L\ U\ dy$ and this causes a frictional force of $L\ U\ \mu\ dy$, acting upward. The cohesive or shearing resistance on the area, $U\ dy$, acts upward, and its amount is $U\ dy\ c$. Placing the sum of the vertical forces acting on the slice equal to zero.

$$V\ A + A\ w\ dy - (V + d\ V)\ A - (L\ U\ \mu + U\ c)\ dy = 0.$$

In reality, an arch or dome of the earth should be considered in place of the horizontal stratum, but the result is the same, because the same vertical forces act in either case. Simplifying the above equation, and dividing by A,

$$d\ V = \left[w - (L\ \mu + c)\ \frac{U}{A}\right] dy.$$

Putting $R = \frac{A}{U}$, and $L = (V - V')\ k$,

$$\frac{d\ V}{dy} = w - \left[(V - V')\ k\ \mu + c\right] \frac{1}{R}$$

$$= w - \frac{k\ \mu\ V}{R} - \frac{c - V'\ k\ \mu}{R} = w - n\ V - q,$$

on placing, $n = \frac{k\ \mu}{R}$, $q = \frac{c - V'\ k\ \mu}{R}$.

It follows that, $$\frac{-n\ d\ V}{w - n\ V - q} = -n\ dy$$

therefore log. $(w - n\ V - q) = -n\ y + C$.

When $y = 0$, $V = V'$,

therefore $\log. (w - n V' - q) = C$,

$$\log. \frac{w - n V - q}{w - n V' - q} = - n y,$$

$$\text{and } \frac{w - n V - q}{w - n V' - q} = e^{-n y},$$

where $e = 2.71828 \ldots.$, the Napierian base.

Solving for V,

$$V = \frac{w - q}{n} [1 - e^{-n y}] + V' e^{-n y}.$$

Substituting the values of n and q, we have,

$$V = \frac{1}{k \mu} [R w - (c - V' k \mu)] \left(1 - e^{-\frac{k \mu}{R} y}\right) + V' e^{-\frac{k \mu}{R} y} \ldots (5)$$

in which it must be remembered that,

$$V' = w h'; h' = \frac{2 c \cos. \phi}{w (1 - \sin. \phi)}.$$

The lateral thrust is now given by,

$$L = (V - V') k \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

To get the pressures, V and L, at the top of the tunnel, replace y by $(h - h')$.

The weight of the upper stratum, of depth h', is in part sustained by the cohesion of the sides, but as h' is generally small, this cohesive force can be neglected, as was done above.

Equations (5) and (6) reduce to the ordinary bin formulas of Janssen, when $\mu = \mu'$, $c = 0$, and therefore $V' = 0$, $h' = 0$. The modification due to these terms is generally small, unless c is very large.

For large values of y, $e^{\frac{-k \mu}{R} y}$ is small, and as y increases indefinitely, V approaches as a limit the value

$$\frac{1}{k \mu} [R w - (c - V' k \mu)].$$

This expression may be derived independently, and is of practical value when a very high surcharge is considered.

Referring to Fig. 20, it is evident that the maximum limit of V would be realized if the weight of any horizontal lamina is entirely

held up by the friction and cohesion of the sides; for then, for all lower slices, V and L remain the same.

Therefore $A\ w\ dy = (L\ U\ \mu + U\ c)\ dy$

$$A\ w = (V - V')\ k\ U\ \mu + U\ c,$$

$$\text{therefore } V = \frac{1}{k\ \mu}\ [R\ w - (c - V'\ k\ \mu)],$$

as given above.

As seen, such a state is not exactly realized, but is practically true for great depths.

For a long tunnel, the perimeter of the section, U, can be taken as $2\ l$, whence,

$$R = \frac{b\ l}{2\ l} = \frac{b}{2}.$$

This value was used in all the computations.

As a numerical illustration of the use of Equations (5) and (6), suppose a tunnel, $b = 15$ ft. wide, and, for the earth covering let $\phi = 45°$; therefore $\mu = \text{tan. } \phi = 1$, $w = 90$ lb. per cu. ft., and $c = 100$ lb. per sq. ft.

We deduce $k = \text{tan.}^2\ (45° - 22\frac{1}{2}°) = 0.172$, $R = \dfrac{b}{2} = 7.5$, $h' = \dfrac{2\ c\ \cos.\ \phi}{w\ (1 - \sin.\ \phi)} = 5.4$ ft., therefore $V' = w\ h' = 486$ lb., $(c - V'\ k\ \mu) = 100 - 83 = 17$.

Equations (5) and (6) readily reduce now to

$$V = 3\ 830\ (1 - e^{-0.023\ y}) + 486\ e^{-0.023\ y},$$
$$L = (V - 486) \times 0.172.$$

These formulas give the vertical and horizontal unit pressures at the top of the tunnel when,

$$y = h - h'.$$

In computing the values of V and L for various depths of earth covering, h, a short table of hyperbolic logarithms is a convenience. The curves given by the equations above are shown on Fig. 17.

An additional note with respect to Equation (1) may not be inappropriate. Scheffler, in deriving this equation, considered the conditions of equilibrium of an infinitesimal wedge of earth at the depth, h. It was found that the horizontal pressure at the depth, h', given by Equation (3), was zero, and it was assumed by the writer that there was no pressure on a vertical plane for a less depth. Thus, in

Fig. 21, there is no horizontal pressure on the plane, DE, where $DE = IC = h'$; consequently, the weight of the wedge, EDB, is supported entirely by the normal reaction of the plane, DB, with the cohesion and friction acting along it.* To deduce Q, the total earth pressure on the vertical plane, AC, it is then admissible to treat the prism, $ADEC$, as the prism of rupture, the surface of rupture consisting of the plane, AD, making the angle α with the vertical and the plane, DE. Therefore W, the weight of the prism, $ADEC$, is in equilibrium with Q, N, and $N f + K$, where N is the normal reaction of AD, $f = \tan. \phi$, and $K =$ the total cohesion on $AD = c \,.\, AD$.

On balancing components parallel and perpendicular to the plane, and then following familiar methods, it can be shown that the true value of Q corresponds to $\alpha = \frac{90 - \phi}{2}$, and that this value is,

$$Q = \frac{w}{2}(h^2 - h'^2) \tan.^2 \left(\frac{\pi}{4} - \frac{\phi}{2}\right) \frac{c\,(h - h') \cos.\, \phi}{\cos.^2 \left(\frac{\pi}{4} - \frac{\phi}{2}\right)}.$$

The derivative of this, with respect to h, gives the intensity, L, at the depth, h, exactly the same as Equation (1), and the subsequent deductions hold. Thus the fundamental Equation (1), according to the interpretation given, is seen to correspond to a prism of rupture, $ADEC$, which is a little nearer the true one, having a curved surface of rupture, than the wedge, ABC.

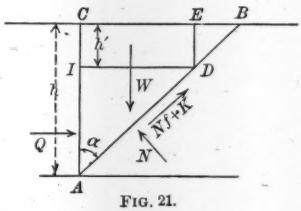

FIG. 21.

The above refers to the pressure on a vertical plane of a mass of level-topped earth of indefinite extent; but suppose that AC is the back of a retaining wall, and that a slight movement downward of the prism of rupture is imminent; then, if the earth along the plane,

* It may be well to remark here, that for cohesive earth, it has been proved, both theoretically and experimentally, that the surface of rupture is curved, and not a plane, as the theory assumes. However, assuming it to be a plane, and considering successive wedges of rupture of different heights, the bases of which lie on the same plane, it can be easily shown that certain of the upper wedges can be sustained by cohesion alone, and that the coefficient of cohesion required for stability varies from 0 at the surface to its maximum value at a certain depth, h_1. Below this depth, friction in addition to cohesion is exerted, and stability is assured if we suppose the friction coefficient to increase from 0 at $h = h_1$ to its maximum value, tan. ϕ at some depth, $h = h'$. Below this depth, on the plane of rupture, the maximum values of both coefficients are exerted. Now, the ordinary wedge theory assumes, for simplicity, that these coefficients are constant all along the plane of rupture, which may be true at the instant of rupture, but not for a stable mass. It is possible, too, that rupture may be progressive, starting at the bottom.

DE, can exert sufficient tension, the mass, *ADEC*, in descending, may drag down the wedge, *DEB*, with it, so that the full friction and cohesion along *DB* will be added to that along *AD*. In other words, the prism of rupture must now be taken as the wedge, *ABC*; hence, the value of Q corresponding is given by the equation above, on making $h' = 0$, as this introduces, in the first equations for equilibrium, the fact that the prism of rupture is now the wedge, *ABC*.

It is only one step farther to find the greatest height at which the vertical face of an open trench will stand for given coefficients, c and f. On making $Q = 0$ in the equation for Q above when $h' = 0$, we find, after reduction,

$$h = \frac{4\ c\ \cos.\ \phi}{w\ (1 - \sin.\ \phi)},$$

a value which has been quoted elsewhere in this paper. It is double the value for h' given by Equation (3). The reason for this, though, is now evident; for the last equation follows as a consequence of assuming that the full cohesive and frictional resistances along *DB* were exerted; whereas Equation (1) ignores them.

DISCUSSION

J. R. WORCESTER, M. AM. SOC. C. E. (by letter).—In reading Professor Cain's admirable paper relating to experiments on retaining walls, the writer has looked in vain for a word of caution as to the effect which time plays in modifying the condition of equilibrium within a mass of earth. The author evidently considers it necessary to allow (by using a factor of safety) for a possible lessening of the angle of friction on account of a change in the amount of moisture, and possible vibrations, but states that in a great majority of cases the greatest thrust will occur where the earth has been recently deposited. It would appear that he neglects a possibility, if not a probability, of a readjustment of the earth particles through the influence of time, by which the angle of friction is lessened if not wholly cancelled. Mr. Worcester.

The theory that cohesion in the earth and frictional resistance on the back of the retaining wall account for the experimental results seems indisputable, but such experiments must needs be carried through in a reasonable time, and, in that respect, at least, must needs differ from actual constructions which are intended to be permanent.

It is well known that unbraced excavations can often be carried vertically to considerable depths in safety, but that not infrequently—as many have learned to their sorrow—such unbraced banks have subsequently caved in. The slides in the Culebra cut may be mentioned as a similar illustration. To be sure, the delayed motion of the earth (or rock) may be attributed to the effect of moisture, but that does not invalidate the argument, as one always has to reckon with water.

It is also a matter of common knowledge that, in braced excavations, the pressure on the sheeting and bracing frequently increases in time to an extent enormously exceeding the original pressure. In many instances this has caused a failure long delayed.

Another instance of the effect of time is found in many retaining walls, in which a very slow motion has occurred, though the walls appeared to be entirely stable when first built.

A frictional or tangential force along the back of the wall may tend to prevent motion, but it is difficult to conceive of this tangential force being perpetually present on the back of a stationary wall after the back-filling has become settled and consolidated. In the interior of the mass of earth at rest the author admits that the reaction between particles is not along inclined lines, but rather that the lines of pressure are vertical and horizontal. The vertical lines of force are, of course, caused by gravity, and the horizontal lines by the tendency of particles to wedge in between those below and to spread them.

Mr. Worcester.

If this conception of the forces within a mass of earth is reasonable, it would seem as if it might also be extended to the pressure against an immovable vertical wall. One must then consider whether it is possible for a horizontal pressure to cause the wall to move, without changing the conditions and introducing the inclined stresses. It would seem within the bounds of possibility that a very minute motion might be produced, and that this would be followed by a readjustment of stresses in the earth by which the forces would gradually resume the horizontal direction.

The nature of the soil undoubtedly has much to do with this question. In some kinds of clay there appears to be a sort of viscosity, such as is frequently seen in pitch and other materials, or a tendency toward a slow flowing. No amount of pressure would cause a sudden motion, but time will effect a motion under a slight pressure or even the force of gravity alone. It appears that this condition is produced by the very minute particles, each moving individually into a position in which the surrounding forces balance. If one cuts a vertical face in such material one cannot force the exposed particles out of their position by crowding them from behind, but each in its turn will feel the pressure unbalanced and will slowly move out. This may not be true to the same extent with granular materials of large diameter, but a familiar instance is seen in fine wet sand. If a small excavation is dug in a wet beach sand, the banks will stand vertically at first, but, by watching closely, one may see the particles, beginning at the foot of the bank where there is most water, gradually moving out, overcoming the force of cohesion, and ever tending to seek a condition with a level surface. It seems quite likely that a similar tendency would exist in almost all soils, to greater or less degree, though perhaps it might be safely neglected in a mass of hard, irregularly-shaped fragments of stone which could interlock.

The point which the writer wishes to make is that a word of caution should accompany this argument for the frictional and cohesive forces; that they cannot always be relied on; and that sometimes the Rankine theory may be better than the wedge theory in designing, even though it does not seem to fit the experimental results.

Another warning may not be amiss, in considering the safe thickness to allow for retaining walls, and that is the effect of frost, where the surface of the ground is level and likely to retain moisture. The swelling force of freezing, under these circumstances, may be more than sufficient to overcome the beneficial effects of both cohesion and friction. Presumably this must be provided for in the "factor of safety," and is in itself a justification for a very appreciable factor.

It may be well to emphasize the fact that a large part of the author's assumed factor of safety seems to be absorbed in keeping the resultant within the middle third of the base. The proportions

Mr. Worcester.

between width of wall and height, determined on pages 433 and 434, are such as to keep this resultant just within the base. If, with these same proportions of wall, the factor were assumed so that the resultant were within the middle third, it would be found to be nearer 1¾ than 3. The author's statement on page 435, that he "does not advocate the middle-third limit method in design," is not wholly clear, but the implication is that the resultant should be well within this limit. In this case, it seems as if the factor of safety would be wholly absorbed in thus locating the resultant, and would leave nothing for other elements of uncertainty.

Mr. Meem.

J. C. MEEM, M. AM. SOC. C. E. (by letter).—In the writer's judgment the author has gone a step forward in developing the relation of cohesion and friction to walls and tunnels, but he has not given sufficient value to the larger consideration of what may be called "cohesive friction" induced by the lateral pressure of earth against retaining walls and other faces. This will be noted later in the discussion.

The author states that "from all that precedes, it is seen that the results of experiments on small models in the past have proved to be very misleading, and that experiments on large models are desirable, and can alone give confidence."* To a certain extent this is fully in accordance with the writer's views, as noted in his papers on earth pressures,† and he feels justified in once more calling attention to the fact that, in his judgment, the only experiments which can definitely establish the value of earth pressures against walls and sheeted faces should be made on a large scale and against independently laid and independently braced horizontal sheeting. If these experiments are made in a homogeneous material, such as dry sand of a known angle of repose, it is believed that it will be conclusively and definitely shown that the pressures at a point above the middle plane will be greater than below it, and, further, that it will be proved that the pressure near the bottom, for example, of a 20-ft. trench, will not be perceptibly greater than that against a brace at the same distance from the bottom of a 40- or a 60-ft. trench.

The writer agrees with the author that the theory of a sliding wedge is the best practical one for retaining walls, and if the face of the wedge be keyed tight, as stated by the author, or through the compacting of the material into a more solid mass, it will be seen that, with no break, the resultant pressures against the wall or face are virtually those, not only of a sliding, but of a solid wedge tending to slide on the plane of repose, the mass being compactly held together by cohesion

* Page 426.

† "The Bracing of Tunnels and Trenches, with Practical Formulas for Earth Pressures," *Transactions*, Am. Soc. C. E., Vol. LX, p. 1; and "Pressure, Resistance, and Stability of Earth," *Transactions*, Am. Soc. C. E., Vol. LXX, p. 352.

Mr. Meem.

induced by lateral pressure. Although the general solidity of this mass is dependent on the stability of the wall or bracing, the pressures caused by the tendency of this solid wedge to slide are not affected materially by slight changes in form due to gradual settlement, which, in turn, may be caused by the normal yielding of the wall or shrinkage of the bracing, or by any small losses of material, as long as any of those or their sum is not sufficient to cause partial or final collapse. Assuming then that this theory of the solid wedge tending to slide is the true one, it is difficult to reconcile it with the results of experiments on revolving boards or revolving walls, except in so far as they relate to the more accurate determination of the coefficients of friction and cohesion.

In connection with the experiments of Leygue, the writer wishes to refer to the dry sand and wheat arching experiments described in the final discussion of his paper, "The Bracing of Trenches and Tunnels, with Practical Formulas for Earth Pressures,"* and especially to the experiment made with dry sand in a 2-in. pipe, described in his paper on "Pressure, Resistance, and Stability of Earth."† For clearer reference, the latter experiment is again described:

A 2-in. pipe, 18 in. long, was filled with dry sand for a depth of 12 in., and a thin piece of tissue paper was pasted across the bottom. Then, with a wooden piston bearing on the sand, the latter would support the blow of a sledge hammer or the weight of a man without breaking the tissue paper.

All these experiments seem to prove very clearly that pressure is distributed laterally, at least through perfectly dry material, and, with certain values known, it should not be difficult to compute the value of this thrust. For example, if, in the pipe experiment, the exact coefficient of friction of the granular particles against the inside of the pipe is determined to be 0.4, then it would take a pressure equal to the complement of this, or 0.6 of the weight, to hold the granular particles against the vertical side. Now, if the exact depth of sand is determined at which no further pressure (by reason of adding to this depth) is transmitted to the bottom, then, by finding the difference or loss of pressure at the bottom, it should be a simple matter to compute the amount of thrust developing sufficient friction over the given area to sustain the additional weight. This is what the writer, for want of a better term, has called "cohesive friction" induced by lateral pressure. While such experiments on a small scale give definite results with very dry sand or wheat, they will not be conclusive unless made on a very large scale in cases where dampness adds materially to the normal cohesion of small masses.

As to the experiments on revolving boards or walls referred to by

* *Transactions*, Am. Soc. C. E., Vol. LX, p. 1.

† *Transactions*, Am. Soc. C. E., Vol LXX, p. 352.

the author, it would appear that, as noted, they eliminate consideration of the effect of pressure as increasing the values of the coefficient of friction and cohesion. Mr. Meem.

The writer believes that it can be shown by Fig. 22 that the lateral pressure against sheeted faces or retaining walls is greater toward the top. Fig. 22 is adapted from Fig. 5 in the writer's paper, "Pressure, Resistance, and Stability of Earth."

It is supposed that a retaining wall has first been built along the face, *A B*, and that it has been back-filled with ordinary dry sand to the curved line *F C;* this is then covered with a heavy canvass or tarpaulin, and Rods 1, 2, 3, etc., are run through it in sufficient numbers to hold it in position when the area, *A F C D*, has been back-filled with dry sand. The tarpaulin is then keyed up tight by the rods bearing on washers of large area on the top plane, *A D*. If the sand in the area, *F E C*, be then removed, the observer is asked to note whether, in his judgment, the resulting pressure is greater at *P* or at *P'*. It must undoubtedly be true that if this experiment establishes the writer's claim in the case of normally dry sand, it will tend to do so much more readily in the case of mixed sands and earths as ordinarily found in trenches. If this fact of the greater pressure toward the top be proved conclusively, as the writer believes it undoubtedly will be in time, it may account for some of the failures of retaining walls.

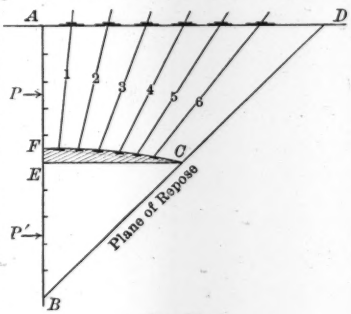

FIG. 22.

It seems that in order to accord our views to the theory of greater pressure at the bottom, we must assume that any given area of the face of a wall is borne on by a prism of material reaching to the top of the bank, and that its pressure is measured by the weight of its cross-section by some multiple of its length. A few moments spent in examining the face of a tunnel drift, or sheeted trench in sharp sand or loam, will convince any one that this cannot be true. In effect, the face of a sheeted trench resists the pressure of what may be termed a series of vertical groined arches, the braces being at the various abutments and the sheeting supporting the more or less loose material between. In no other way can the fact be explained that individual sheeting planks may frequently be removed for a short time without danger, even when the bracing shows evidence of very heavy pressure; whereas the removal of even a single brace may cause collapse.

A few years ago the writer was called to examine a 44-ft. trench which had collapsed. While it will probably never be known definitely

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how or where the failure first occurred, it may be of interest to note that within 50 ft. of the break and under conditions apparently similar to those which had existed there previously, the writer found intermediate sheeting planks near the bottom, behind which the pressure was not sufficient to force them out against the rangers, whereas no one could for a moment doubt that there was pressure against the braces or on the sheeting directly behind them. In order, then, that experiments on retaining walls or sheeted faces may be of value, the pressures must be measured against areas absolutely independent of each other; and the writer believes that this can best be done as stated heretofore.

The author states:

"However, if, from any cause, such as insufficient sheeting, the break has taken place over even a part of *A I B E*, the mass, *A F*, above will tend to tip over at the top, giving the greatest pressure on the top braces. This appears to explain the phenomena observed by Mr. Meem and others in connection with some trenches."

The writer thinks it is unfortunate that the author has not had an opportunity of visiting with him many trenches in which no break had occurred, and yet in which the bracing had to be strengthened continually near the top. This was especially true of a horizontally sheeted and braced shaft of large area. The writer believes that it is not out of place to express the hope that the author may still change his viewpoint, and may eventually regard only as phenomena well-braced trenches which in sand or gravel do not show evidences of heavier pressure near the top.

Referring now to tunnel pressures, the author states:

"If there was no settlement of the earth, *D C F E*, in relation to *D C*, * * * but, as most of the weight of *D C F E* is carried by the sides, in case of sufficient settlement, the vertical unit pressure, *V*, on *D C*, will be much less than *wh*."

The writer would criticize this view because it brings in the element of settlement as essential to its conclusions, and, therefore, is contrary to his belief that all earth is under stable conditions due to the lateral transmission of thrust due to weight, thereby causing the "cohesive friction" previously noted. This transmission of thrust results in what may be termed "arching stability," which is unchanged when small areas of hard, dry ground are undermined. When normally dry soft ground is disturbed, however, there is a gradual settlement of tiers of strata, and as those above are, in turn, left without support, they settle on what may be termed a new centering and form themselves into new arches. If these strata are composed of sand and gravel, with little natural cohesion, the action of this settlement will be similar to that observed in an hour-glass and will "work" to the

surface in a short time. It should be noted, however, that as the voids below are filled and solidified by the pressure, the lateral thrust of this pressure causes the arching tendencies to be resumed again in each successive stratum, relieving the lower strata of the pressure or shock of fall from those above. Mr. Meem.

The tables given by the author on Figs. 17 and 18, show that the pressure per square foot on the roof of a 15-ft. tunnel at a depth of 150 ft., for instance, is approximately double that on the same tunnel at a 50-ft. depth. This assumption is not justified by any facts which have ever come under the writer's notice or have been brought to his attention. The observation of any tunneling operations in soft normally dry ground, or the examination of existing structures, will convince any one that, after a depth of approximately twice the greatest diameter of opening has been reached, it is impossible to tell, by any difference in the pressure, the depth of the tunnel. While numberless instances could be cited to illustrate this fact, two which have come under the writer's notice may be of interest.

In the case of a 15-ft. tunnel passing the bed of an old underground stream, a considerable amount of ground was lost through the influx of sand which came in with the water. For several days after this the writer examined the surface directly overhead for evidences of settlement, and after some 4 or 5 days he found a hole some 12 ft. in diameter and 8 or 10 ft. deep, which was at once filled in. Had the mass of earth of this area and some 20 to 60 ft. high come down on the timbering suddenly, without any intervening "arch cushion," it would undoubtedly have crushed it; and yet none of the night men had been conscious of even the slightest shock.

In the other case, a heavy rain had caused a large pond to form over the heading of a 15-ft. tunnel, and before it could be drained away it broke through the unprotected face of the heading, virtually filling the whole tunnel with sand for some distance. This, however, had not caused the collapse of any of the bracing, and, before work could be resumed, it was necessary to re-excavate the material. This material was used to fill in the hole caused by the cave-in, and when operations were finally resumed, about 10 days later, the sectional shields, which had remained in position undisturbed, were started with less than the ordinary pressure, as indicated by the gauge on the hydraulic pump.

The writer confidently believes that the assumption behind the reasoning by which the table in Fig. 17 was made is fallacious, and that the fallacy is found in the following quotations:

"In answering this question, it must be remembered that, of the weight of earth directly over the tunnel, all has been transferred to the sides that it was possible to transfer, for the coefficients of friction and cohesion given. We know scarcely anything of the cohesion

Mr. Meem. coefficients, so that the value assumed, $c = 100$ lb. per sq. ft., may not be near the truth. Certainly it must appear plain from this discussion that the values of c and ϕ must be better known, for all kinds of earth, before reliable results can be attained."

* * * * * * * * *

"In reality, an arch or dome of the earth should be considered in place of the horizontal stratum, but the result is the same, because the same vertical forces act in either case."

* * * * * * * * *

"Referring to Fig. 20, it is evident that the maximum limit of V would be realized if the weight of any horizontal lamina is entirely held up by the friction and cohesion of the sides; * * *"

* * * * * * * * *

"As seen, such a state is not exactly realized, but is practically true for great depths."

Referring to the last quotation, the writer would go further and say that if the assumption is true that the spaces above a tunnel are considered as a series of horizontal layers dependent on the natural coefficient of friction and cohesion (not added to by pressure) to hold them up, that it would appear to be far preferable to calculate always on full pressure to the top than to assume that some of these strata may be sustained by what would appear to the writer to be largely chance conditions.

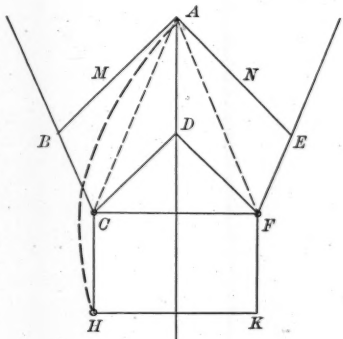

FIG. 23.

It would appear that the author has considered cohesion and friction only as normally found in exposed faces, and as they would be developed between contiguous vertical columns of earth through which pressures were transmitted laterally; and, in tunnels as against vertical faces, he does not appear to have given sufficient weight to the essential factor that cohesion and friction, combined into what the writer has previously termed "cohesive friction," are increased by the pressure in some definite relation to it.

If, for example, on a tunnel section, *C F K H*, Fig. 23, a centering or core of sand, *C D F*, is assumed, and over this a mass, *A B C D F E*, composed of magnetic particles which cause them to adhere to each other, it is not difficult to conceive that a thickness at the key, *A D*, would be reached where the core, *C D F*, could be removed. The same result, approximately, may be reached by assuming that the

mass is sand or earth and is supported by the core, *C D F*. As, however, in this case the lower part of the arch along *C D F* is composed of loose material, the support of some of it must be provided for in the area where the blending of the arch and the core is indeterminate. This supported area is arbitrarily assumed to be *A C D F A*, or half *M C D F N A*, the point, *A*, being determined as far as possible by experiment to be at the intersection of the vertical, *D A*, and the line, *C A*, bisecting the angle between that of repose and the vertical. These general deductions, exclusive of the exact determination of the location of the point, *A*, appear to be borne out by all the experiments previously noted and others in the writer's papers hereinbefore referred to, and in the author's observations on grain bins, as noted in the following quotation from his paper: Mr. Meem.

"In the many experiments on high grain bins, the enormous influence of the friction of the grain against the vertical walls or sides of the bin has been observed. In fact, the greater part of the weight of grain, even when running out, is sustained by the walls through this side friction. This furnishes another argument for including wall friction in a retaining-wall design."

Not only is this "an argument for including wall friction," but it seems to prove that this friction is increased relatively to the pressure, and that under stable conditions coherence is also induced by the pressure and friction.

The writer is much gratified to find that the author concurs in the view that the area of water pressure is reduced in subaqueous tunnels and other submerged structures in sand or earth, and he concurs heartily with the author that experiments on a large scale, to determine the values of this reduction definitely with relation to the various materials, will be of the greatest value to the Profession.

WILLIAM CAIN, M. AM. SOC. C. E. (by letter).—The writer is gratified by Mr. Worcester's words of commendation. The walls or boards subjected to earth pressure were of various inclinations, and the surface slope of the earth was equally varied. A theory which stands the test of experiments in such variety seems to be pretty well established. If the various theories that have been proposed from time to time were subjected to this test, how many would survive? And yet no theory can claim to be a practical one unless it is found to agree fairly well with experiments. Mr. Worcester seems to think that the effect of time on retaining walls ought to be included. The effort was made to do this, by using a factor of safety and by multiplying only the normal component of the thrust on the wall by this factor, taken as 3 for ordinary cases; where the effect of frost is decided, the factor should be increased, and the back of the wall, for say 3 or 4 ft. down from the top, should be sloped forward to allow Mr. Cain.

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the earth, in the expansion incident to freezing, to push its way up the inclined plane corresponding.

If railway trains pass near a retaining wall, their weight should be replaced by an equal weight of earth, which is regarded as dead weight in computing the thrust. Vibration probably increases the thrust, and this increase moves the top of the wall over slightly, on account of the yielding of the earth foundation about the outer toe. On account of the imperfect elasticity of earth, this deformation may remain and increase in time, and thus lead to the ultimate failure of the wall. This lack of spring, or recovery, in the earth foundation, is probably the main cause of the increased leaning of walls with time. The remedy is to build a foundation course of masonry, projecting in front of the wall, of such width that the true resultant on its base shall pass through its center. The base, too, should be inclined, in order to prevent sliding. Of course, efficient drainage must be secured by the use of weep-holes and perhaps drains back of the wall.

Mr. Worcester is of the opinion that the friction against the back of the wall is not a permanent feature, and suggests the Rankine formula as possibly a better one for design. For a surcharge of sufficient inclination, and especially when it slopes at the angle of repose, the Rankine thrust involves more friction at the back of the wall than the method illustrated in Fig. 15, where only one-third of the friction is used for ordinary cases; but, even granting, for the sake of argument, that at some time this friction is null and that subsequently rains and vibration cause an increased thrust, then the top of the wall moves over slightly, the earth will again get its frictional grip on the wall, so that this friction is always exerted when required for stability.

It is, perhaps, customary to design a wall so that the resultant on its base shall pass one-third of the width of base from the outer toe. This procedure gives very different factors of safety, as hitherto defined, for different types of walls. The writer's method aims to give equal security to all ordinary walls, by using a constant factor of safety.

The writer is gratified that Mr. Meem has again recorded some of his valuable experiences, but regrets that he cannot regard some of his theories as convincing. With regard to the center of pressure on a retaining wall backed by fresh earth, Mr. Meem maintains that the intensity of pressure increases from the bottom upward, so that the center of pressure lies above the horizontal plane drawn at mid-height. This view has been shown to be untrue by experiment. Thus:

(1) Leygue, in the experiments referred to on page 420, found the value of the moment of the earth thrust about the inner toe,

and also determined the plane of rupture. Using the corresponding wedge of rupture, the writer computed the normal component of the thrust. On dividing the moment by this, the distance of the center of pressure from the base was found to be, as an average, for all experiments on sand, 0.34 of the height, and for millet seed, 0.405 of the height.* Mr. Cain.

(2) The easily made experiment of Mr. Gifford† on the deflection of a cardboard retaining wall shows that the resultant thrust lies nearer the base than the top of the wall.

(3) All the experiments discussed on pages 407-427 agree with the latter statement.

(4) The resultant earth thrust on a wall must approach indefinitely water thrust as ϕ approaches zero. The latter is known to act at one-third of the height above the base.

(5) If a triangular wedge of rupture is assumed, it follows inevitably that the unit pressure increases with the depth, and that the resultant acts at one-third of the height above the base. This follows because the total pressure then varies with the square of the height, as in water pressure.

(6) Let the contrary be assumed—that the pressure increases from the base upward—then, in a great depth of earth, the pressure at the top would be enormous enough to crush the hand if thrust in the earth. As everyone knows, the pressure on the hand is very slight, and this shows the absurdity of the hypothesis.

It may be stated now that the proposed experiment, referring to Fig. 22, would not prove Mr. Meem's contention. For, if the earth below *FC* was removed, the thrust on *AF* would have to be sufficient to prevent the whole mass, *AFCD*, from descending, which is far greater than *P*, which balances only the thrust of the wedge of rupture, the inclined base of which passes through *F*.

A conclusive experiment could be made on a high retaining wall, backed by sand or grain (not in a bin, but unconfined except by the wall) after Jamieson's manner in the case of grain bins, by inserting the rubber diaphragms, etc., at various points from the top down, and measuring the pressures.

In respect to the distribution of pressure, the theory of the sheeted trench differs materially from that of the retaining wall. Much confusion has arisen from confounding them. On that account, and to meet many interesting points made by Mr. Meem, the writer will give a thorough discussion of retaining walls and sheeted or unsheeted trenches, backed by coherent earth.

For an unlimited mass of level-topped earth, having both friction and cohesion, but ignoring the cohesion along the vertical plane, *DE*,

* See the writer's "Retaining Walls," sixth edition, p. 132.

† *Transactions*, Am. Soc. C. E., Vol. LX, p. 84.

Mr. Cain. Fig. 24, it was shown in the Appendix that the horizontal pressure on a vertical plane, AC, is that due to a certain prism, $ADEC$, and that its total amount, in pounds, is,

$$E = \frac{1}{2} w y^2 \tan.^2 \left(45° - \frac{\phi}{2}\right) \ldots\ldots\ldots (7)$$

where w is the weight in pounds of 1 cu. ft. of the earth, c is the cohesion of the earth, in pounds per square foot, $y = h - h' = AC - IC = AI$,

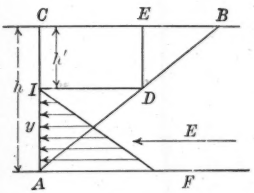

FIG. 24.

$$h' = IC = \frac{2\ c}{w} \frac{\cos.\ \phi}{1 - \sin.\ \phi} = \frac{2\ c}{w} \tan. \left(45° + \frac{\phi}{2}\right) \ldots\ldots (8)$$

The plane, AD, is found to bisect the angle between the natural slope and the vertical when E is horizontal, as shown by Fig. 24.

The value of E is given just below Equation (4) in the Appendix. It acts at $\frac{1}{3} y$ above the base, since the distribution of stress on AI is linear.

It follows, because Equation (7) is the usual one for the thrust of non-coherent earth of depth y, that the total horizontal stress on AC of the earth endowed with cohesion, is exactly the same as that due to the same earth, but devoid of cohesion, having a free horizontal surface, ID, extended indefinitely in both directions, at a depth h', as given by Equation (8), below the original free surface. The theory ignores any possible cohesion acting upward along DE, or any tension in the mass that may possibly drag down part of the wedge, EDB, and thus decrease the thrust, E.

The formula is thus seen to give a thrust greater than the true one, or what may be called an upper limit. To realize the hypothesis more clearly, it may be said that if a vertical crack in the earth is assumed along DE, the resulting value of E will be the same as that given by Equation (7). It is a fact of observation that sometimes earth which has been saturated and then dried out, cracks along one or more vertical planes. This indicates tension in the mass, which is overcome, however, at certain points (only) and thus vertical cracks appear.

In the construction of Fig. 11, the full friction and cohesion which can be exerted on the length, AB (of Fig. 24), is supposed to be exerted. This construction then gives a lower limit to the thrust. As to which hypothesis will lead to the most probable value, it may be observed that the broken line of rupture, ADE, Fig. 24, is nearer the true curved line of rupture (which is assigned both by theory and the facts of observation) than the straight line, AB; hence, the hypothesis leading to Equation (7) seems to be the more probable one.

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In the case of the open trench, suppose AC to be a vertical side of the trench; if A lies below the level of ID, and a crack exists along DE, then, undoubtedly, the mass, $ADEC$, will move to the left, because there is an unbalanced force, E, to cause the motion.

The vertical height of an unsupported bank, where vertical cracks occur of depth h', will then be that given by Equation (8), which is one-half the value usually given. This is generally an extreme lower value; for any earth endowed with much cohesion must be capable of exerting tension. If the tension exerted is sufficient to drag down DEB (which can stand unsupported), that is, if the wedge, ABC, acts as a whole, then the free unsupported height will

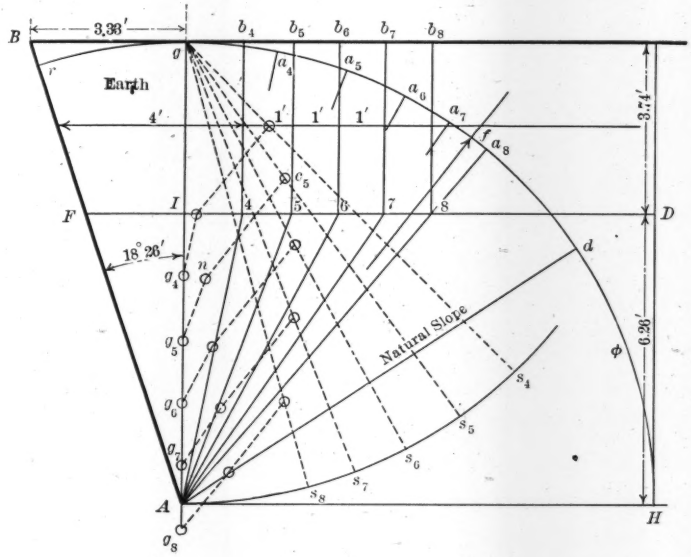

FIG. 25.

be double that given by Equation (8). This is evidently an extreme upper limit, perhaps rarely attained; for vertical cracks have often been observed to precede a fall of earth into a vertical trench. For $w = 100$, $\phi = 35°$, and $h' = 23$ ft., Equation (8) gives $c = 600$, whereas the usual equation gives $c = 300$ lb. per sq. ft. The true value is possibly between these two extremes.

Recurring again to earth pressures, the discussion pertaining to Fig. 24 suggests the following modification of the graphical method of Fig. 11 to adapt it to finding the pressures of coherent earth against retaining walls, for the case supposed above. In Fig. 25, let AB be the

Mr. Cain. inner face of a retaining board or wall, which is backed by earth with a horizontal surface $B\,b_8$. The vertical height of the wall is 10 ft. and the physical constants are assumed as follows: $\phi = 33°\ 41' = \phi'$, $w = 100$, and $c = 100$. From Equation (8),

$$h' = \frac{2\,c}{w} \tan. \left(45° + \frac{\phi}{2}\right) = 3.74 \text{ ft.}$$

Now lay off, vertically downward from the free surface, a distance, $h' = g\,I = 3.74$ ft. (to scale) and through I draw a line, FID, parallel to the top surface. By Equation (7), the thrust on any vertical plane as $b_4\,4$, $b_5\,5$, ..., is null, and any tension and cohesion that may actually exist along any of these planes will be ignored. This is equivalent to supposing vertical cracks along these planes, which leads to an increase of the thrust and is thus on the side of safety.

The weights of the successive trial prisms of rupture, $A4\ b_4\ B$, $A5\ b_5\ B$, ..., are now laid off to scale, along some vertical, as $g\ A$. The successive weights are represented by the vertical lines, $g\,g_4$, $g\,g_5$, ..., $g\,g_8$. The points b_4, b_5, ..., were taken 1 ft. apart; hence the area, $A4\ b_4\ b_5\ 5$ = the area $A5\ b_5\ b_6\ 6$, etc.; so that, after computing the area $A4\ b_4\ B$, the areas $A5\ b_5\ B$, etc., can be found by successive additions. These areas, multiplied by 100, give the weights, in pounds, of the successive prisms of rupture for 1 ft. length of wall. As before, two arcs are drawn with the same radius ($A\,g$), with centers A and g and having laid off the angle, $HA\,d = \phi$, the chords $A\,s_4$, $A\,s_5$, ..., are laid off equal to chords $d\,a_4$, $d\,a_5$, ... The lines, $g\,s_4$, $g\,s_5$, ..., now make angles with the normals to the planes, $A4$, $A5$, ..., respectively, each equal to ϕ. Also, lay off the chord, $d\,f = g\,r$; then $A\,f$ gives the direction of the reaction of the wall, AB (directly opposed to the earth thrust), inclined at the angle, $\phi' = \phi$, to its normal.

Next, measure, to the scale of distance, the length, in feet, of any line of rupture, as $A5$. Multiply this number by $100 = c$, to get the force of cohesion, in pounds, acting up along $A5$, and lay it off, to the scale of force, from g_5, on a line parallel to $A5$, to n. Similarly, lay off the cohesive forces, acting along $A4$, $A6$, ..., at g_4, g_6, ..., and from points, such as n, lines are drawn parallel to the direction of the thrust, $A\,f$, to the intersections with the corresponding rays, $g\,s_4$, $g\,s_5$, ... Suppose $n\,c_5$ to prove the greatest of these segments, then $n\,c_5$, to the scale of force, gives the earth thrust on AB, in pounds. In the present instance, the plane of rupture lies midway between $A5$ and $A6$, and the corresponding thrust is 1 440 lb. For purposes of illustration, regard $A5$ as the plane of rupture; then the forces acting on the prism, $A5\ b_5\ B$, are represented by the sides of the closed polygon,

$$g\ g_5 n\ c_5 g;$$

$g\,g_5$ representing its weight, $g_5 n$, the cohesion acting up along $A5$, $n\,c_5$ the reaction of the wall, and $c_5\,g$ the resultant of the normal reaction, N, of the plane, $A5$, and the friction, N tan. ϕ, acting along it. As stated, the actual plane of rupture is found (by drawing one or more additional trial planes) to lie midway between $A5$ and $A6$.

If it should be deemed desirable to include the cohesion acting upward along the vertical planes, $b_4\,4$, etc., it is very readily done. At each point, such as n, draw vertically upward a line of length (to scale of force) $= c\,h' = 100 \times 3.74 = 374$ lb., to represent the force of cohesion acting along the corresponding plane. From the extremities of such lines, parallels to $A\,f$ are drawn to the intersections with the corresponding rays, of the type, $g\,s$. As before, the greatest of these lines represents the thrust on AB. Its amount, in this instance, is 1 240 lb. It is seen, especially when $h' = g\,I$ is one-half of $g\,A$ or more, that the change in thrust is quite appreciable.

Lastly, if each plane, as $A5$, is extended to the surface and considered to offer full cohesive and frictional resistances throughout its whole extent, the construction of Fig. 11 applies, and gives a thrust of 1 220 lb., practically the previous amount.

As mentioned before, in connection with Fig. 24, this supposes sufficient tension in the mass to drag down the triangle, DEB. Suppose, now, $A\,g$ to be the face of a trench which will just stand unsupported for the height, $A\,g$, when the cohesion along $b_4\,4$, $b_5\,5$, ..., is included. Then, if, from the drying out of the earth, causing contraction near the surface and possibly changes in c and ϕ, cracks occur along some of these planes, the resistance to motion of the corresponding prism of rupture is decreased, and the mass will move down, unless, in the meantime, sufficient bracing has been put in. This well illustrates what constructors tell us of the importance of getting in well-keyed-up bracing in time to prevent any crack from developing, which, as we have seen, largely increases the thrust. Even when cracks do not appear, a heavy rain, shortly after a trench is opened, is a frequent cause of falls; evidently because c and possibly ϕ have been very materially decreased.

To compare the results of this very general graphical method with those given by analysis, as expressed by Equations (7) and (8), let AB be taken vertical or coinciding with $A\,g$, regard the thrust on $A\,g$ as horizontal, and neglect any cohesion on the vertical planes, $b_4\,4$, etc. Then it is found, for the given constants, that the graphical method gives exactly the thrust (560 lb.) obtained from Equation (7). This result was foreseen.

It is likewise interesting to know, if the thrust on $A\,g$ is taken as parallel to $A\,d$, or making the angle, ϕ, with the normal to $A\,g$, that the thrust on $A\,g$, as given by the construction, is again found to be the same (510 lb.) as that given by a well-known formula for

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the thrust on the plane, *AI*, for earth devoid of cohesion and having a free surface, *ID*. The importance of these conclusions lies in this: that for the wall vertical, the earth surface horizontal, the earth thrust being horizontal or otherwise, the shorter method is available. If preferred, the thrust on the wall, *AI*, for the earth devoid of cohesion, with the free surface, *ID*, for either direction of the thrust, can be evaluated by the graphical methods (page 404) hitherto given.

Since this paper was written, Résal's *"Poussée des Terres," Deuxième Partie,* on Coherent Earths, has appeared.* In it the author gives an exhaustive discussion of lines of rupture for a great number of cases. The equivalent of Equation (7) is found for the case of the horizontal pressure on a vertical plane when the free surface of earth is horizontal; but it was found to be impracticable to derive a formula for the earth thrust for the general case of the earth surface sloping at an angle to the horizontal, the wall being either inclined or vertical. In fact, for such cases, the intensity of the earth thrust at any depth is not a linear function of the depth, as obtains in the case shown by Fig. 24. Hence Résal resorts to the following approximation: Conceive a line drawn parallel to the surface, at a depth, h' (as given by Equation (8)), below it, and regard this line as the free surface of non-coherent earth of the same specific weight and angle of repose as the given earth; compute the thrust against the wall for such earth, devoid of cohesion, by methods pertaining to such earth; the thrust thus found is assumed to be approximately the true thrust on the wall for the original coherent earth. It is proper to state that Résal rejects the sliding-wedge theory for non-coherent earth, and uses a method of his own, which involves elaborate tables given in his book. The wedge theory is admittedly imperfect, mainly because the surface of rupture is a curve, but we have seen that it agrees with experiments on model walls or retaining boards, when properly interpreted, and it will be used, as before, in computing the earth thrusts, E', below, for earths devoid of cohesion. The graphical method has already been indicated.†

In Table 6 comparative results are given for various cases, including those already examined. Each retaining board was supposed to be 10 ft. high, the earth to have a natural slope of 1 on 1½, and to weigh 100 lb. per cu. ft.

α = the inclination of the inner face of the wall to the vertical; tan. α will be considered as positive when the top of the wall leans toward the earth, otherwise negative;

i = the angle the surface of the surcharge makes with the horizontal;

* This is reviewed in *Engineering News*, January 19th, 1911.

† The formulas used will be found in the writer's "Retaining Walls," sixth edition, p. 96, *et seq.*

c = the cohesion, in pounds per square foot;
ϕ' = the assumed inclination of the thrust to the normal to the face of the wall; Mr. Cain.
E = the thrust for coherent earth, found by the writer's construction, the general case being shown in Fig. 25; in this the cohesion along the vertical planes was omitted;
E' = the thrust for non-coherent earth, by the usual methods, where the new surface of the non-coherent earth is supposed to be a plane parallel to the original surface, and at a distance h', as given by Equation (8), below it; at this depth, it can be rigorously proved, for any surface slope, that the thrust is zero.

TABLE 6.

Case.	Tan. α.	Tan. i.	c, in pounds per square foot.	ϕ'	E, in pounds.	E', in pounds.
1.....	$-\frac{1}{3}$	0	100	ϕ	1 440	880
2.....	0	0	100	0	560	560
3.....	0	0	100	ϕ	510	510
4.....	0	$\frac{1}{3}$	100	ϕ	660	750
5.....	0	$\frac{2}{3}$	100	ϕ	880	1 630
6.....	$+\frac{1}{3}$	0	50	18°26′	240	490

It is seen, by comparing the values of E and E', in Table 6, that, except for Cases 2 and 3, where the coincidence in the results has been already noted, the thrusts by the two methods differ very widely, hence the second method must be rejected, as in some cases undervaluing the thrust, and in other cases overvaluing it. In Case 5, where the surcharge slopes at the angle of repose, the large excess is due principally to the ordinary theory for computing E', involving an infinite plane of rupture, as hitherto noted.

In Case 6, where the top of the wall leaned toward the earth, c was first assumed equal to 100, but it was found to give no thrust against the wall; which means that the earth would stand unsupported at the slope $\frac{1}{3}$ or with the face making an angle of 18° 26′ with the vertical, when this face was 10 ft. high. Hence, a second trial was made, with $c = 50$, with the results shown. It will be noticed that ϕ' was assumed as 18° 26′, so that the thrust was taken horizontal. In fact, Résal asserts that the thrust against such a leaning wall, makes a less angle than ϕ with the normal to the wall. According to his tables, ϕ, for this wall cannot exceed 20° 40′. As the wall approaches the vertical, ϕ', approaches ϕ, the exact value given for a vertical wall. By comparing the thrusts, E, for Cases 1 and 6, the economy of using the latter type of wall is so apparent that it is astonishing that constructors do not adopt it oftener.

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The general conclusion to be drawn from Table 6 is that, except for Cases 2 and 3, the general graphical method of Fig. 25 must be used for accuracy. If applicable to the case in hand, the cohesion along the vertical planes, $b_4 4$, etc., can be included with very little additional labor. The graphical treatment given is so general and the theory involved is so apparent to the eye, that it seems to commend itself as a practical treatment of a very complicated problem.

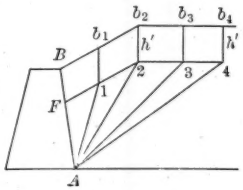

FIG. 26.

The general method illustrated in Fig. 25 can also be applied to the surcharged wall of Fig. 26. Here, the lines, $F2$ and 24, are drawn parallel, respectively, to $B\ b_2$ and $b_2\ b_4$, and vertically, $h' = 2b_2 = 4b_4$ ft. below them. The trial prisms of rupture are of the type, $A3\ b_3\ b_2 B$. Their weights are laid off as before, on the line, $g\ g_8$, of Fig. 25, and the further construction is exactly as there indicated. It is assumed here that the slope of $B\ b_2$ does not exceed the natural slope, for, if it does, the construction is somewhat altered.

It may be asked whether the construction of Fig. 25, where the cohesion on the vertical planes, $4b_4$, etc., is omitted, if applied to the experiments on rotating boards, will appreciably alter the results given in Table 3. The answer is no; for, when $c = 1, w = 80$, therefore $h' = 0.046$ ft., or is very small. In fact, as in the experiments, no cracks were formed, the cohesion on the vertical planes should be included, which would lead to the results given.

After the thrust, for earth endowed with cohesion, has been computed, the next question is, at what point on the retaining wall does it act? This can be answered at once, when the inner face of the wall is vertical and the earth surface horizontal, for then the earth thrust acts at $\frac{1}{3}$ of the height, AI, Figs. 24 and 25, as hitherto proved. The case is not so simple when the wall is inclined, either toward or from the earth. In Fig. 25, the thrust, $n\ c_5$, on the wall, AB, must be decomposed into horizontal and vertical components. The horizontal component is the resultant of the horizontal forces acting from F to A which may be assumed to follow the linear law; hence this component will act on AF at a point, distant $\frac{1}{3}\ AF$ from A, going from A to F. The vertical component, similarly, will be regarded as acting on AB, at a distance $\frac{1}{3}\ AB$ from A. The same approximate rule is suggested when AB lies to the right of the vertical, Ag.

When the earth surface slopes at the angle of repose, the distribution of stress is not linear, but more like that shown in Fig. 10. As the

equation of the corresponding pressure curve cannot be found, an approximation only can be suggested. When $\frac{h'}{h}$ is (say) less than one or two tenths, the factor, $\frac{1}{3}$, above, can be used; but as $\frac{h'}{h}$ increases toward its limit, 1, the factor increases toward some unknown limit. Probably it does not exceed 0.4 even for Fig. 26, and, for want of accurate knowledge on the subject, it may be taken at 0.4 as a rude approximation.

Finally, when the surface slope is less than the natural slope of the earth, then as it decreases from tan. ϕ to zero, the factor should decrease from the extreme value (say 0.4) to $\frac{1}{3}$. Résal takes this factor at $\frac{1}{3}$ for all cases, which is certainly not on the safe side.

The case of the retaining wall which receives the active thrust of the earth has been hitherto examined, and next the case of the braced trench will be discussed. As the trench (having vertical sides) is dug, the usual sheeting, rangers, and bracing are put in and the bracing is kept well keyed-up, so as to exert an active pressure on the earth. To illustrate the theory, in Fig. 25, let Ag represent the vertical side of the trench, the earth extending only to the right of Ag. Then from points such as n, draw horizontal lines to the intersection with the corresponding gs; the longest of these lines, to the scale of force, will represent the total force that must be exerted by all the braces, per foot of length of trench, to prevent any motion of the mass. As has been seen, this force is given by Equation (7). If a still greater force is exerted by the braces, less than a certain value which would just cause motion of the earth up some plane of rupture, stability is completely assured.

As a numerical illustration, assume a trench 40 ft. deep and 15 ft. wide, the constants for the earth being, $\phi = 33° 41'$, $c = 100$, $w = 100$. Then, by Equation (8), $h' = 3.74$ ft. and $y = h - h' = 40 - 3.74 = 36.26$ ft. Hence, by Equation (7), the least force the braces must exert per linear foot of trench is,

$$\frac{1}{2} w y^2 \tan.^2 \left(45° - \frac{\phi}{2}\right) = 50\ (36.26)^2 \times 0.2\ 866 = 18\ 844 \text{ lb.}$$

Suppose the braces to be 10 ft. apart horizontally, and that there are six braces in the same vertical plane. The least force that the horizontal braces must exert on 10 lin. ft. of trench is 188 440 lb., and if each carries the same stress, the force to be exerted by one, is $\frac{188\ 440}{6} = 31\ 407$ lb. Assuming a unit stress of 800 lb. per sq. in. for an 8 by 8-in. wooden brace, 15 ft. long, it is seen that one

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brace can safely exert a force of 51 200 lb., which is greater than the least amount required, as should be the case to allow for changes in c and ϕ due to heavy rains. To meet such contingencies, 10 by 10-in. braces are suggested. Of course, very little is now known as to the coefficient, c, but, from the observed heights of trenches which have stood without sheathing, it is probable that values of c from 100 to 300 lb. per sq. ft. can be counted on for most trenching. For the present, the only safe way is to be guided by experience, such as has been elicited by Mr. Meem's paper, "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures."

As to the exact distribution of the stresses, theory cannot speak definitely, for the conditions are different from those in the case of the retaining wall, the passive resistance of which opposes the active earth thrust. For the braced trench, the earth, at first, simply resists the active pressure exerted by the braces, when first put in and keyed-up tight, particularly on that upper portion where the active earth thrust is nothing or very small. As the construction proceeds, the braces will receive more and more of the active earth thrust, which necessarily increases with the depth of trench. In fact, the distribution of stress, indicated by the arrows in Fig. 24, although true in the case of a retaining wall, where the earth has been deposited behind it, is not necessarily or generally true in a sheeted trench, because of the manner of its construction. Thus, in digging a trench, the bracing is put in at intervals, but when a brace is inserted near the bottom of the trench, the digging is continued for several feet without bracing, until a depth is attained at which it is thought best to insert another brace. Before the latter is put in, the unprotected face of the trench, say 6 ft. in depth, can exert no pressure, as it would in the case of the retaining wall. The thrust that would be exerted, for this area, on the supposed wall, does not exist for the unsupported face of the trench, for the full horizontal thrust of the earth for the whole depth has been taken up by the braces above the unsupported area. This state of affairs is characteristic of the work as it proceeds, the lowest brace that is put in at first carries only the stress due to the keying-up, but takes more and more stress as the excavation proceeds. It can thus very well happen that the upper or the middle braces may receive more stress in the end, than the lower braces. In fact, this was asserted to be generally true, for well-drained material, by many engineers in the valuable discussion on Mr. Meem's paper referred to. Other engineers advised caution in accepting this view, and asserted that in wet or saturated ground the lower braces were most severely stressed. If it were possible to force a board of a size equal to the length and depth of a trench, vertically downward, excavate and brace, all in a millionth of a second, then one can conceive that the distribution of stress shown in Fig. 24 might be realized; but, for trenches as actually constructed, the distribution of stress in the earth mass

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is very much altered from this, though it would appear that the total earth pressure would be given, at least approximately, by the construction of Fig. 25, or by the use of Equation (7).

The writer hopes that Mr. Meem may agree to the foregoing explanation, for the subject of trenches was entered into in great detail, in order to explain, if possible, all the facts, as presented by many engineers who held very diverse views about the explanation of them. Mr. Meem's Fig. 22 can illustrate the writer's view: if bracing only extends, say, from A to E, then the braces must exert sufficient horizontal thrust to prevent the descent of the wedge, say $AB\,3$, if this gives the maximum thrust for the coherent earth.

Turning now to pressures on tunnels, the writer is pleased to note that Mr. Meem has recorded some more of his experiences concerning them. From lack of proper knowledge of the so-called constants, k, c and ϕ, such experience is an aid in leading to more probable values.

As the writer proceeds in this investigation, he hopes to make clear the conception of arch action alluded to, and will derive the limiting values of V and L in the simple manner outlined briefly in the Appendix. Before considering these matters, however, it may be well to call attention to the fact that a vertical prism of earth can be held up by the cohesion of its sides alone when c is large enough. Take the vertical prism of depth h and cross-section area A, Fig. 20, its weight being $w\,A\,h$. In a long tunnel, two sides only can be counted on to furnish cohesive forces. Call U the perimeter available in any case. Then the cohesive force is $c\,U\,h$, and this alone (without reference to any friction that may act) will support the prism when, $c = w\dfrac{A}{U} = w\,R$. In the long or completed tunnel, $R = \dfrac{b\,l}{2\,l} = \dfrac{b}{2}$ (see notation of Appendix); but if we take a short section at the heading, say $l = \dfrac{b}{2}$, then support can be derived from three sides, and $R = \dfrac{\frac{b^2}{2}}{2\,b} = \dfrac{b}{4}$. Thus if we assume the horizontal cross-section of the prism to be 15 by 7.5 ft., $c = 90 \times \dfrac{15}{4} = 338$ lb. per sq. ft., where $w = 90$ lb. per cu. ft. Thus, such a vertical prism of any height, at the heading, can be sustained by a cohesion of 338 lb. per sq. ft. acting on three of its sides. This refers to a tunnel 15 ft. wide. For the completed tunnel 15 ft. wide, the part vertically over the tunnel can be supported if the two sides can furnish double this unit cohesion. The term $(w\,R - c)$ will apear in an equation mentioned later. It is seen now that when this term is zero, cohesion alone can sustain

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the prism, and the pressure reduces to zero. When this term is negative, it indicates that too large a value of c has been assumed, for stability is assured for $c = w\ R$.

In reference to Fig. 16, it was stated that a series of superposed arches or domes were assumed, but that since the reactions of the horizontal laminas of Fig. 20 and corresponding arches were the same, the former were substituted for convenience. If each arch has the vertical thickness, dy, it will have the same volume and weight, $A\ w\ dy$, as the horizontal lamina. The reactions marked on Fig. 20 can be assumed to be those of the corresponding arch, and the resultant of the horizontal and vertical reactions represents the thrust of the arch at the sides; its direction will be that of the tangent line of the arch. When c is small, the horizontal reaction is much greater than the vertical one, and the arches are all very flat. Now, considering the whole series of arches, it is plain that the greatest or limiting value of V (call it simply V) would be realized if the weight of any arch is entirely held up by the friction on the sides (induced by the lateral thrust) and the cohesion acting there; for then this same condition of affairs would exist for all lower arches,* and thus V is transmitted vertically downward, unchanged, to the tunnel. Stating this condition in algebraic form,

$$A\ w\ dy = (L\ U\ \mu + U\ c)\ dy.$$

This equation strictly holds for large values of y, but it is practically true for much smaller values. For such values, h' is quite small compared with y and can be assumed as equal to zero, whence V' will also be taken equal to zero and the usual bin formula, $L = V\ k$, written.†

On substituting this value in the equation above, reducing and placing $R = \dfrac{A}{U}$, we obtain,

$$V = \frac{1}{k\mu}\ (w\ R - c)\ ;\ L = k\ V = \frac{w\ R - c}{\mu} \quad \ldots\ldots\ldots\ (9)$$

where, $\mu = \tan.\ \phi$.

In the Appendix, the writer assumed, $k = \tan.^2\left(45° - \dfrac{\phi}{2}\right)$, basing this value on the results pertaining to a smooth steel bin, 1 ft. in

* This assumes that the values of k and c do not decrease for the greater depths.

† In the Appendix, the "semi-empirical" formula, $L = (V - V')\ k$, was assumed. It gives fairly correct values for small values of y, but for c large and y large, it departs more from the truth than was at first surmised. Hence, by the reasoning above, V' will be made zero throughout, and Equations (5) and (6) of the Appendix will be changed to

$$V = \frac{1}{k\mu}\ [Rw - c]\left(1 - e^{-\frac{k\mu}{R}y}\right) \quad \ldots\ldots\ldots\ (5)'$$

$$L = V\ k \quad \ldots\ldots\ldots\ (6)'$$

Equations (5)' and (6)' will not give accurate results for y small, which is of no importance, as such values are never used; but they should give practically accurate results for the larger values of y.

diameter, filled with sand. From the experiments of Jamieson on large wooden bins, about 12 by 12 ft., filled with wheat, k was found to be 0.60. Janssen determined k experimentally to be 0.67. For wheat, Jamieson gave $\phi = 28°$; whence $\tan.^2\left(45° - \frac{\phi}{2}\right) = 0.361$. His experimental value was $\frac{10}{6}$ of this; hence, for lack of definite data, there will be assumed for earth, Mr. Cain.

$$k = \frac{10}{6} \tan.^2\left(45° - \frac{\phi}{2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

From the last three equations, the values of V and L have been computed for various values of c, b, ϕ, and R, and are given in Table 7.

TABLE 7.

c, in pounds per square foot.	b, in feet.	ϕ	V, IN POUNDS PER SQUARE FOOT.		L, IN POUNDS PER SQUARE FOOT.	
			$R = \frac{b}{4}$	$R = \frac{b}{2}$	$R = \frac{b}{4}$	$R = \frac{b}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
100	15	30°	740	1 790	410	1 000
100	30	30°	1 790	3 900	1 000	2 160
100	15	45°	830	2 010	240	570
100	30	45°	2 010	4 370	570	1 250
400	15	30°	0	860	0	480
400	30	30°	860	2 960	480	1 640
400	15	45°	0	960	0	270
400	30	45°	960	3 320	270	950

The pressures given in Columns 5 and 7 are intended to apply to a long section of a tunnel, those in Columns 4 and 6 refer to a short section about the heading. The values for $c = 100$ are intended to apply to what Mr. Meem styles "soft normally dry ground," and it is hoped that he may approve the figures, as they are somewhere near his own. The coefficient, $c = 400$, refers to hard consolidated ground. Here the pressure is 0 at the working faces of the 15-ft. tunnel. Fig. 27 shows the variation in V for $c = 100$, $b = 15$, $\phi = 30°$, for some of the larger values of y, as obtained by the revised formula given in the foot-note. It will be observed that the above demonstration for finding the limiting value of V, is perfectly independent of Janssen's formula. In it the relation, $L = V k$, is only assumed to be true for this one value of V, and k need be determined by experiment only for this value. The result is thus general, no matter how k varies for other values of V. A glance at all the diagrams,* giving the experimental values of V and L for various depths, will show that k is far from

* Ketchum's "The Design of Walls, Bins and Grain Elevators," pp. 253–282.

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being a constant for varying depths, though the assumption is found to lead to practical results, as obtained from Janssen's formula. The experiments of Jamieson on 12 by 13½ by 67½-ft. wheat bins, and of Bovey on 12 by 14 by 44 ft. 10-in. bins, both of wood, indicate that the maximum pressure, V, is realized, practically, for heights of about four diameters. Pleissner's experiments on a wooden bin, 11.51 by 8.20 ft., show four and a half diameters, and Luft, for a concrete bin, 23 ft. in diameter, gives, say, three diameters, for the height corresponding to maximum V.

These are wide variations, resulting from variations in k and the

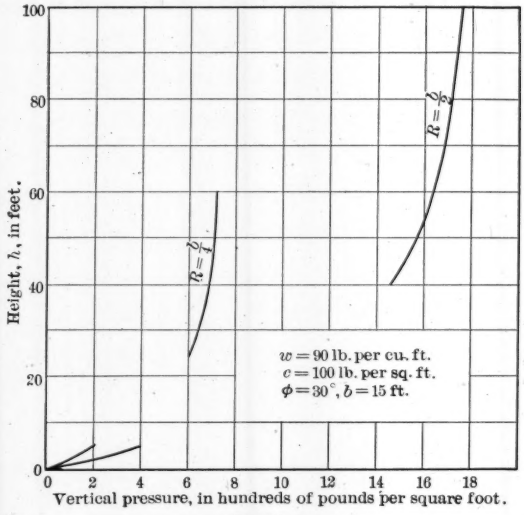

FIG. 27.

coefficient of friction of the wheat on the walls of the bin. As k increases, this ratio of height to diameter decreases. It would appear to be a serious objection to the use of Equations (5)′ and (6)′ if this ratio for maximum V was large, but it must be remembered that k, for earth over tunnels, is not known. It is possibly larger than assumed. In any case, Equations (9), which were deduced independently of the modified Janssen formulas, appear to hold.

The writer has read with much interest the very interesting "dry sand and wheat arching experiments," referred to by Mr. Meem. It is seen from the above, that the writer believes in this arching of sand under certain conditions, for example, after some settlement. He does not see any reason for any arching in an unlimited mass of sand, level

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at the top. The conjugate pressures here are vertical and horizontal; but, if a tunnel is bored through this mass, it tends to sink over the tunnel, and, only in consequence of that settlement, is a part of the weight of the sand directly over the tunnel transferred to the sides through the friction caused by the lateral thrust and the cohesion. Neither of these forces, both acting vertically upward, were in action, before the settlement. Mr. Meem gives the following account of an interesting experiment:

"A 2-in. pipe, 18 in. long, was filled with dry sand for a depth of 12 in., and a thin piece of tissue paper was pasted across the bottom. Then, with a wooden piston bearing on the sand, the latter would support the blow of a sledge hammer or the weight of a man without breaking the tissue paper."

Considering the sand in the pipe alone, it affords a pretty illustration of the bin theory. Here, $R = \frac{A}{U} = \frac{\pi}{2\pi} = \frac{1}{2}$. Take $\phi = 30°$ and $k\mu = \frac{10}{6} \tan.^2\left(45° - \frac{\phi}{2}\right)$, tan. $\phi = 0.32$; also $w = \frac{90}{1728}$ lb. per cu. in. Therefore, making $c = 0$ in the formula for V above, we have $V = \frac{w\,R}{k\,\mu} = \frac{1}{0.32} \times \frac{45}{1728} = 0.0814$ lb. per sq. in. Hence the total pressure on the tissue paper is $\pi V = 0.256$ lb., or say $\frac{1}{4}$ lb. Perhaps the paper can stand this. The pressure is reduced to 0.185 lb. on the paper if we include cohesion, taking $c = 1$ lb. per sq. ft., as deduced from Leygue's experiments on dry sand. This pressure would not be increased if the pipe, supposed to be vertical and filled with sand, was of great height, the weight of the additional sand being equal to the weight of the man or to the pressure induced by the blow of the hammer. It seems natural, then, to infer that the pressures due to the blow or man, are sustained by the sides of the pipe, as in the case of the sand, though the conditions are not the same. In fact, in this case, the pressure on the paper is even less than before; for the blow, or the weight of the man causes the passive lateral thrust of the earth to be exerted, and this, for $\phi = 30°$, is nine times the active thrust hitherto used, at least for an unlimited mass of earth. If this ratio is assumed to hold for the sand in the pipe, the value of $k\,\mu$ will be changed to 9×0.32, and the total pressure on the paper will be only

$$\frac{1}{9} \times \frac{1}{4} = \frac{1}{36} \text{ lb.}$$

It is hoped that experimenters may turn their attention to finding definite values of the coefficient of cohesion for all kinds of earth. From observations of unsupported trenches, it has been seen that values of c of from 100 to possibly 400 lb. per sq. ft., may be ex-

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pected. Résal states* that MM. Jacquinot and Frontard, in July and August, 1910, made some preliminary experiments on earth taken from a reservoir dam which was failing, and found for it about $c = 2\,000$ kg. per. sq. m., or say 409 lb. per sq. ft.; but tan. $\phi = 0.14$, corresponding to $\phi = 8°$. The latter result is startling. For finding c and tan. ϕ experimentally, Résal suggests that a thin slice of earth be placed between two rough metallic plaques, pressed firmly together, and that the resistance to the relative displacement of the two plaques, for varying pressures, be recorded. By writing the relation between c, tan. ϕ, and the forces involved, for each experiment, values of c and tan. ϕ can be found by elimination. In conclusion, the writer believes that he has offered a satisfactory and comprehensive theory of earth pressure, for earth endowed with both cohesion and friction. The results are not on as satisfactory a basis for pressures on tunnels, but the formulas derived are submitted in the hope that engineers will subject them to the test of both experience and experiment.

The writer returns sincere thanks to Messrs. Worcester and Meem for their helpful and stimulating discussion.

* "*Poussée des Terres*," *Deuxième Partie*, p. 827.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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TRANSACTIONS

Paper No. 1193

THE WATER-WORKS AND SEWERAGE OF MONTERREY, N. L., MEXICO.*

By George Robert Graham Conway, M. Am. Soc. C. E.

With Discussion by Messrs. James D. Schuyler, David T. Pitkethly, George S. Binckley, Vicente Saucedo, George T. Hammond, Rudolf Meyer, and George Robert Graham Conway.

Introductory.

Monterrey, the Capital of the State of Nuevo León, Mexico, is built on the site of the old village of Santa Lucía de León, which was established in 1583 by the Governor of the Kingdom of León, Don Luis Carabajal. Four years later Carabajal was imprisoned by the Inquisition, and the village of Santa Lucía was abandoned by its few inhabitants.

In 1596, Captain Diego Montemayor, a resident of Saltillo, in the adjoining State, wishing to render a service to his king, Philip II of Spain, assembled his friends, and on September 20th of that year, proceeded to establish a town on the site of the old village on the northern side of the principal spring at the place. The town was named "Nuestra Señora de Monterrey" (Our Lady of Monterrey), after the Count of Monterrey (Ojos de Santa Lucía y Valle de Extremadura), the ruling Governor of New Spain, as Mexico was then called.

* Presented at the meeting of February 1st, 1911.

Monterrey is approximately in the center of the State of Nuevo León, 1° 12′ west of Mexico City, and in latitude 26° 40′ N. It is a distributing railway center on the main line of the National Railroad, 270 km. from the Rio Grande at Laredo, 1 022 km. from Mexico, and 520 km. from Tampico by the Mexican Central Railway. It is the center of many large industries, and is the second largest manufacturing city in the Republic.

The Concession.

The works described in this paper were carried out under a guaranteed concession granted by His Excellency, General Bernardo Reyes, Governor of the State of Nuevo León, to Messrs. James D. Stocker and William Walker, of Scranton, Pa. The concession is dated October 19th, 1904, and is for 99 years from that date; the works for a complete water and drainage system were to be finished in 3 years from the time of their commencement. Before the works were designed and begun, the concession was acquired by Mr. William Mackenzie, of the firm of Mackenzie, Mann and Company, Limited, of Toronto, Ont., Canada, who, on May 4th, 1906, organized the Monterrey Water-Works and Sewerage Company, Limited (Compañía de Servicio de Agua y Drenaje de Monterrey, S. A.), under the laws of the Dominion of Canada, of which company he is President. Mr. Mackenzie is also President of the Monterrey Railway, Light, and Power Company, Limited, which was constructing the street railways of Monterrey concurrently with the water-works. Under the provisions of the concession, the Government appointed a Financial Interventor, who had authority to examine and check the company's expenditures, and also a Technical Inspector to examine and report on the construction. The duties of these officials also apply to the operation of the system when the construction is finished. The Government has the right, after the system has been operated 40 years, to purchase the entire property, subject to 6 months' notice, for a sum equal to $16\frac{2}{3}$ times the average annual net proceeds during the 3 preceding years. This right may be exercised at the end of 40 years, or at the end of any 10-year period thereafter, up to 99 years from the commencement of operations.

Geology and Topography.

Monterrey lies in a plain at the foot of the Eastern Sierra Madre Mountains which constitute the eastern margin of the Mexican Cor-

PLATE II.
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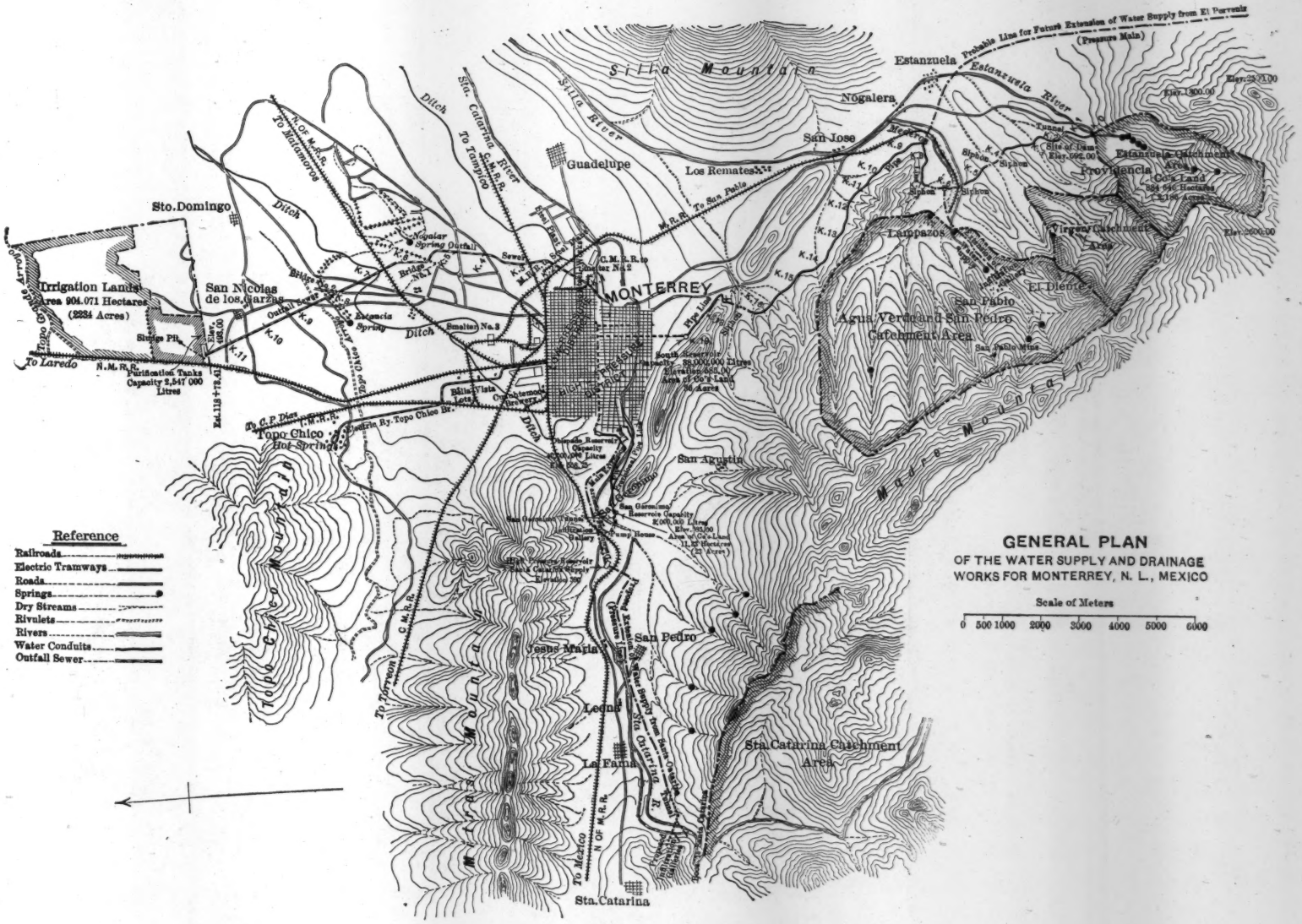
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



dilleran Plateau, and is surrounded by the magnificent mountains of that group, among the most notable of which are the beautiful Mitra and Silla Mountains. In the neighborhood of Monterrey these mountains attain heights of from 2 000 to 2 400 m., and are noted for their broken and jagged sky-lines. The leading geological characteristics of the district are the uplifted limestones of the older cretaceous age which form the main mass of the mountains.

Primarily, the mountains are compressional folds which, in the Sierra Madre, near Monterrey, are close and vertically compressed.* The drainage areas of the Santa Catarina River, which flows through Monterrey, and of the Estanzuela and Silla Rivers, its tributaries, are of limestone and shale; originally the shales were above the limestone, but the convulsion which formed the Sierra Madre as an anticlinal fold, left the originally horizontal strata standing nearly upright, and subsequent erosion in the upper part of the anticline has exposed nearly vertical strata in many places. The limestone being hard and resisting erosion, there is generally, along the line of contact, an abrupt drop vertically on the face of the limestone to the shale below. In many places this abrupt drop is broken by a limestone talus, but the line of contact can generally be traced. Mining operations in these mountains have revealed the presence of large caves at a considerable elevation, many of which contain large reservoirs of water, delivered to them through numerous faults. The river valleys are formed of masses of limestone conglomerate and coarse gravels, re-cemented in many cases by the lime deposits of the flowing waters. One of the chief characteristics of the subsoil of Monterrey itself is a local rock called "sillar," which is a superficial deposit of carbonate of lime from the evaporated waters. In some places the "sillar" is largely mixed with a conglomerate called "tepetate," or "impure sillar."

Topographically, the region around Monterrey is distinguished by the drainage area of the River Santa Catarina, which rises in the Sierra Madre near the Laguna de Sanchez, at an elevation of 1 850 m., as shown on Plate II. From this Laguna it follows a tortuous course between precipitous mountains through the Boca of Santa Catarina to Monterrey, for a distance of 90 km., eventually finding

* *Transactions*, Am. Inst. Min. Engrs., Vol. XXXII (1902), pp. 163-178.

its way to the San Juan River, a tributary of the Rio Grande. Throughout its course it disappears, flows underground, and again appears; and, except in flood time, it has a subsurface flow for a distance of 16 km. above the city. In the Cañon of Santa Catarina it appears at the surface, having a normal flow of about 1 415 liters (50 cu. ft.) per sec., and its waters at that point are divided into two parts and carried into irrigation canals. The drainage area of the river above Monterrey is 1 410 sq. km., and its bed at Monterrey is between 518 and 545 m. above sea level.

Southward from Monterrey the country rises along the valley of the Silla for a distance of 19 km., where the Silla is separated from the San Juan by a low divide, the former flowing northward to Monterrey and the latter southeastward toward Allende. The Silla Valley is bounded on the east and west by the steep ranges of the Silla and Sierra Madre Mountains. The floor of this valley is gently rolling, but is cut by many arroyos which carry little or no water during the greater part of the year. The chief feeder of the Silla River is the Estanzuela, a stream which derives its waters from several springs coming to the surface near the line of contact between the limestone and the shale, at elevations of about 800 and 900 m.* above datum. The water-shed of this stream is rich with abundant vegetation due to the precipitation being greater than on the Santa Catarina water-shed. To the south of the divide the country is well wooded, and El Porvenir, 35 km. from Monterrey, is the garden spot of the State of Nuevo León. Here the rainfall is much greater than at any other point near Monterrey, and there are many streams which are used for irrigation purposes. Monterrey is built on a plain, chiefly on the north side of the Santa Catarina River. This plain has a general fall toward the northeast, and beyond the city it slopes gently northward for several miles toward the Topo Grande River, and then southeastward to join the great coastal plain of the Gulf of Mexico. The general elevation of the city lies between the 519- and 550-m. contours. The Plaza Zaragoza, in the center of the city, is 533.90 m. above sea level; the elevation of the highest part of the city, at the western boundary, is 550.05 m., and of the lowest part, at the northeastern boundary, 518.0 m. above sea level.

* Throughout this paper datum refers to the height in meters above the mean sea level of the Gulf of Mexico at the Port of Tampico.

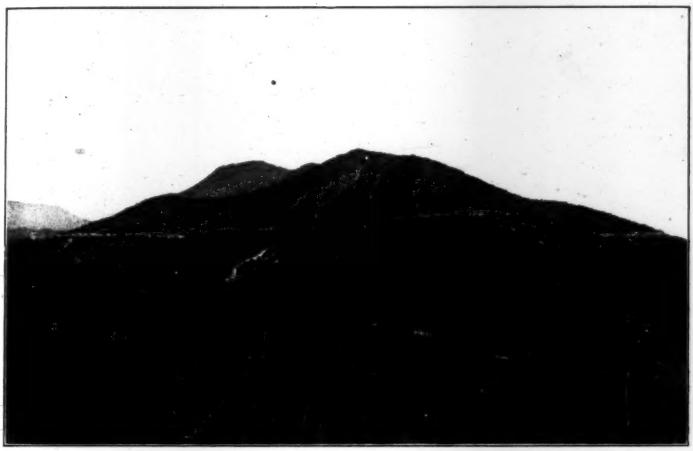


FIG. 1.—GENERAL VIEW OF LINE, ESTANZUELA AQUEDUCT.

FIG. 2.—STEEL FORMS FOR MOULDING CONCRETE TUBES, ESTANZUELA AQUEDUCT.

Population, Area, and Mortality.

The population of Monterrey has increased as follows:

Census of	1851	14 621
" "	1861	26 000
" "	1871	33 811
" "	1881	39 456
" "	1891	41 154
" "	1901	73 508
(Estimated)	1909	86 000 to 90 000

The greatest progress, it will be noted, was between 1891-1901, with an increase of more than 22 000 in 10 years. In designing the new works, provision has been made for the future requirements of a city of 200 000 persons.

The actual area within the city limits proper is 960.5 hectares (2 374 acres), forming the area to be provided with water and drainage, but the municipal district extends to many surrounding suburbs, and covers an area of 33 758 hectares (83 426 acres).

TABLE 1.—Population and Death Rate of Monterrey, N. L., Mexico, from 1901 to 1909, Inclusive.

Year.	Population.	Deaths from all causes.	Rate per 1 000.	Deaths from typhoid fever.													Deaths from typhoid fever per year per 10 000 population.
				Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total for year.	
Census 1901..	73 508	2 965	40.3	0	2	1	3	4	3	6	6	3	6	4	2	40	54
Estimated 1902..	74 500	3 338	44.8	1	4	2	3	6	5	3	1	1	2	3	5	36	48
" 1903..	76 000	3 825	50.3	3	2	4	1	0	5	3	5	6	16	3	1	49	64
" 1904..	77 500	2 905	37.4	0	1	1	5	3	3	3	4	1	5	1	0	27	35
" 1905..	79 000	2 951	37.4	2	0	0	3	3	7	6	3	2	7	2	2	37	47
" 1906..	80 000	2 935	36.7	1	2	1	3	3	6	5	3	2	1	2	3	32	40
" 1907..	82 500	3 269	39.6	4	6	3	3	5	6	4	4	9	3	0	3	50	61
" 1908..	84 000	3 188	37.9	5	2	5	3	8	5	9	7	2	7	4	0	57	68
" 1909..	86 000	*3 477	40.4	5	1	4	5	13	11	15	12	6	8	3	4	87	101

* Excluding deaths due to drowning in the great flood of August 27th and 28th.

Table 1 gives particulars of the death rate for 1901 to 1909, inclusive, and data relative to the mortality due to typhoid fever. The high death rate is caused by the excessive infantile mortality, which is so prevalent throughout the whole of Mexico. The climatic condition of Monterrey, with its exceptionally healthy subsoil, ought to make it one of the healthiest of cities, if proper care were taken to enforce sanitary laws. The data regarding typhoid mortality are probably

understated, as they were compiled by the writer, in the absence of any official publications, from the actual death certificates, but no special care is taken by the authorities to insure accuracy in such certificates. Attention is called to the typhoid rate in May, June, July, and August, 1909; this high rate coincides with a scarcity of rainfall and the greatest period of drought experienced in 30 years, and immediately precedes the great flood of August 27th. It was probably due to the lowering of the ground-water throughout the city and the consequent contamination of the private wells, which were largely in use during that time. Throughout the city the wells are sunk to a depth of about 12 or 15 m., in order to reach the subterranean waters, and the cesspools are often in dangerous proximity to them and at a much higher level. The nature of the subsoil, which is often much fissured and open in the conglomerate and sillar strata, would make the passage of contamination an easy matter, and this alone would account for a high mortality due to water-borne diseases.

Rainfall and Temperature.

The precipitation records of Monterrey and its neighborhood are very meager, and cannot be relied on for a longer period than from 1894 to 1909, inclusive. The records are available from 1886, but in the early years there are many apparent discrepancies, and they are probably inaccurate. The average rainfall for the 15 years (1894-1908) is 21.94 in.; the driest years for this period are as follows: 1894, 14.14 in.; 1902, 15.29 in.; 1907, 15.23 in.; 1908, 15.11 in. Assuming the early records to be correct, the average rainfall for the period, 1886-1908, would be 19.86 in.

At Saltillo, which is 50 miles due southwest, at an elevation of about 1 520 m. above sea level, the average rainfall for the 23 years, 1884-1908, inclusive, is given as 21 in. The maximum year was 1889, with 33½ in., and the minimum 1903, with 7½ in.

At Carmen, in the State of Tamaulipas, 144 km. southwest of Monterrey, at an elevation of about 310 m. above sea level, the average fall for 12 years is 24.70 in., the maximum year being 1897, with a fall of 34.09 in., and the minimum year, 1905, with 13.41 in.

Fig. 1 shows the annual variation of rainfall at Monterrey for 1894-1909. Fig. 2 shows the monthly variation during the same period, and gives the minimum, average, and maximum for each month.

FIG. 1.—TYPICAL REINFORCED CONCRETE GIRDER BRIDGE, ESTANZUELA AQUEDUCT.

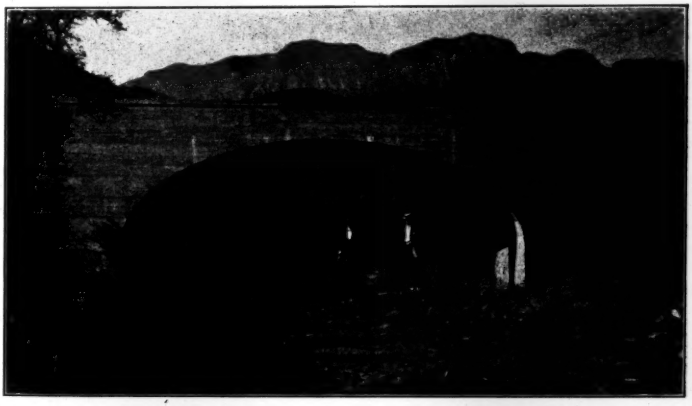


FIG. 2.—ELLIPTICAL ARCH BRIDGE CARRYING ESTANZUELA AQUEDUCT.

From these diagrams it will be seen that the months of least rainfall are December, January, February, and March, with averages of 0.66, 0.59, 0.79, and 0.93 in., respectively. The months of greatest rainfall are August, with an average of 4.39 in., and September with 4.87 in. The maximum in any month prior to 1909 was 16.75 in., during September, 1904.

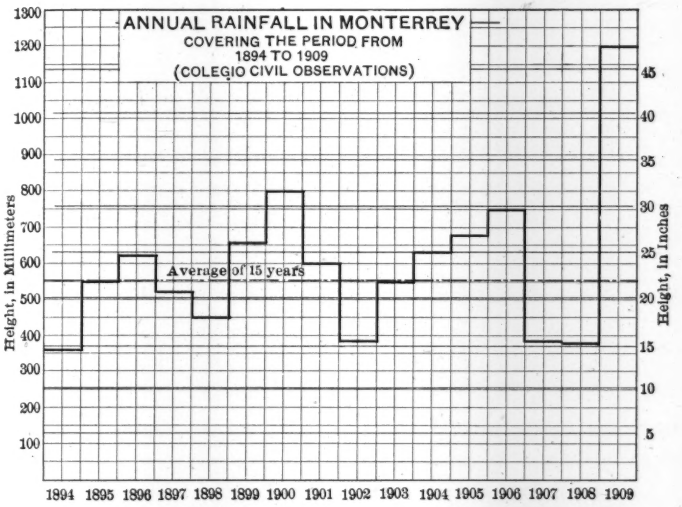


FIG. 1.

Rainfall in 1909.—The rainfall in 1909 was unprecedented, causing the disastrous flood in the Santa Catarina River, which will be referred to when describing the works. Fig. 3 shows the monthly rainfall for 1906 to 1909, inclusive, and has been plotted to show the variation of rainfall prior to the great precipitation of August, 1909. In that month there were two heavy falls, one beginning at midnight on August 9th, and during the following 42 hours a fall of 13.28 in. was recorded by the gauge at the Water-Works Company's general offices, 10.20 in. of which fell during the first 24 hours. From 6 P. M. to 11 P. M., on August 10th, 5.019 in. were recorded, or an average of 1 in. per hour.

After 13 dry days, another rainstorm began, at 4 P. M., on August

25th, and continued more or less intermittently until August 29th. During this 98-hour period there was an additional fall of 21.61 in., 11.27 in. falling in 24 hours.

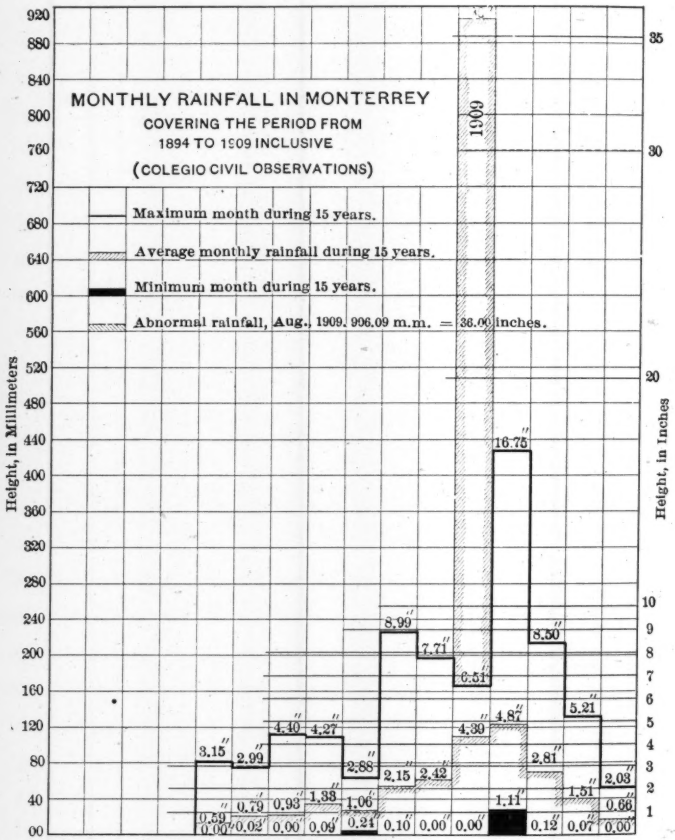


FIG. 2.

The total precipitation during the month amounted to 36.00 in. The highest previous record for the month of August was in 1895, with a fall of 6.61 in. Fig. 4 gives the details of the two heavy precipitations in August. As no automatic recording gauge was available,

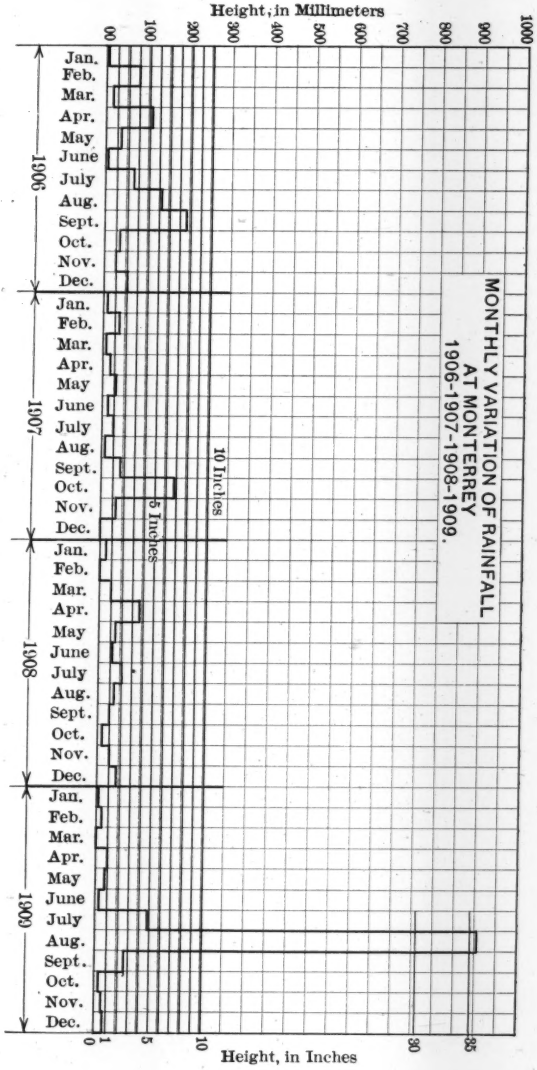

Height, in Millimeters
0
100
200
300
400
500
600
700
800
900
1000
1906
1907
1908
1909
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
10 Inches
5 Inches
MONTHLY VARIATION OF RAINFALL AT MONTERREY 1906-1907-1908-1909.
0
1
5
10
20
25
Height, in Inches

Fig. 3.

the maximum intensity could only be computed approximately, owing to the intermittent character of the readings taken from the ordinary rain gauge on the roof of the Water-Works Company's office in the city. From the readings thus obtained, it was shown that the maximum intensity occurred early on the morning of the 28th, and was nearly 2 in. per hour. Above Monterrey, in the Santa Catarina watershed, it is believed that the precipitation was considerably greater, but no gauges were accessible during the month.

The total rainfall for 1909 amounted to 47.46 in., of which 75% fell in August. This is 50% greater than the previous highest annual record (31.65 in. in 1900) for Monterrey.

Temperature.—Fig. 6 gives a record of the temperature at Monterrey from 1901 to 1909, inclusive. These records were taken at an altitude of 520 m. It will be noted that the lowest recorded temperatures are in January and February. The lowest during these years was 24° Fahr., in January, 1905. The monthly maxima vary between 80 and 110° Fahr. The mean annual temperature is 72.65° Fahr. (The mean annual barometer is 28.2 in.)

Available Sources of Supply.

The question of the best sources from which Monterrey should be supplied with potable water was one that had been long under discussion, and was the subject of many investigations prior to the granting of the present concession. Several of the original schemes called for an impounding reservoir in the Cañon of Santa Catarina, and it was on the assumption that a dam would be built that a clause was inserted in the concession for the purpose of making its construction obligatory. The general character of the physical and geological conditions surrounding Monterrey has already been referred to. A thorough study of these conditions proved that no suitable site for impounding the Santa Catarina River could be found, apart from the fact that periodically this river is subject to enormous floods which tear through the steep cañon with tremendous velocity.

At the site originally proposed for the dam, a considerable underflow was found, and later investigations, carried out under the present concession, proved that, although borings were carried to a depth of 54 m., bed-rock could not be found, the strata being composed of gravels, conglomerate and sand. Assuming that such a dam could

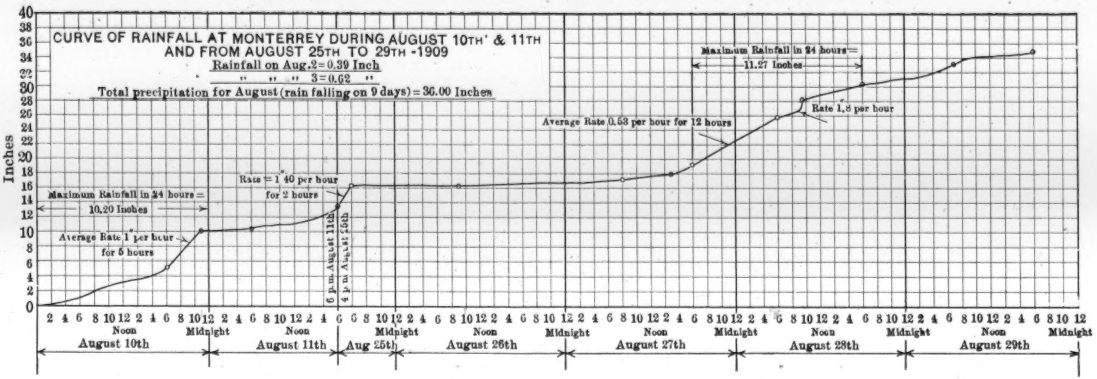
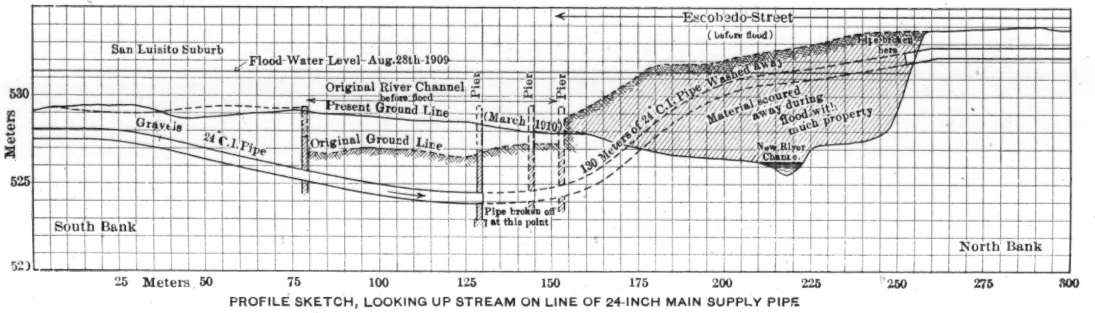


FIG. 4.



PROFILE SKETCH, LOOKING UP STREAM ON LINE OF 24-INCH MAIN SUPPLY PIPE

FIG. 5.

have been built, the quality of the water draining from a comparatively barren water-shed, on which many thousands of goats are pastured, would have made its filtration an absolute necessity before it could be delivered to the consumers.

The various available sources from which water could be delivered to the city by gravity were investigated by Mr. F. S. Hyde, in the autumn of 1905, and also by J. D. Schuyler, M. Am. Soc. C. E., who was afterward retained as Consulting Engineer for the Company. The various investigations made from time to time showed that the question of a satisfactory supply was one of extreme difficulty, requiring prolonged observation and study, more particularly into the character of the underground sources of supply.

One of the chief characteristics of many of the streams in the State of Nuevo León, is their disappearance and reappearance at different points along their routes, and the Santa Catarina River, under normal conditions, as already remarked, is a very notable example of a river which is very dry at the surface for many kilometers of its length. In the writer's opinion, the waters of this and similar rivers in the State pass through many open caverns underground, so that experience gained in the investigation of underflow waters in other places would be insufficient to determine the quantity passing at any point along the river if ascertained by merely computing it from the velocity of the underflow and the area of the water-bearing gravels. The rainfall on the water-shed of the Santa Catarina River is probably 25% greater than at Monterrey, and all ordinary rains sink rapidly into the limestone soils and quickly disappear. In another water-shed of a very similar character, namely, that of the Rio Blanco, in the southern part of the State, the underflow waters appear at the surface at a place called Mezquital, where a metamorphosed sandstone barrier prevents them from disappearing underground. At this point the normal quantity of water is about 5 660 liters (200 cu. ft.) per sec., but it gradually disappears, and a few kilometers below it has sunk to an insignificant stream, finally disappearing altogether for about 20 km. In the neighborhood of Monterrey similar conditions exist with regard to the surface-water supplies, and investigations, therefore, were directed toward obtaining unpolluted supplies from springs and underground sources.

Santa Catarina Sources.—The chief points from which it was

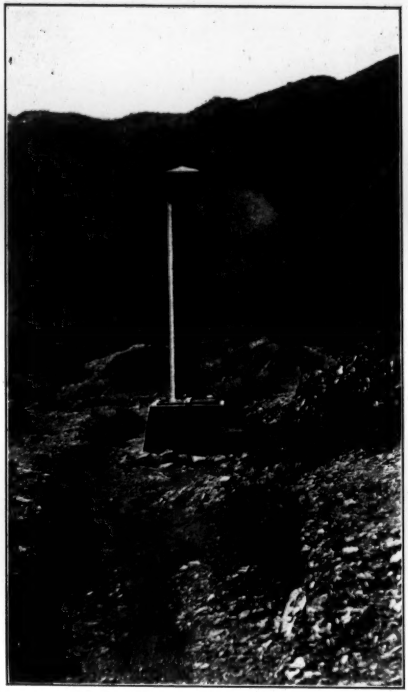


FIG. 1.—VENTILATING COLUMN AND ENTRANCE MANHOLE, ESTANZUELA AQUEDUCT.

FIG. 2.—PLACING CONCRETE PIPES IN FORMS FOR BRIDGE CROSSING AT NORTH END OF TUNNEL, ESTANZUELA AQUEDUCT.

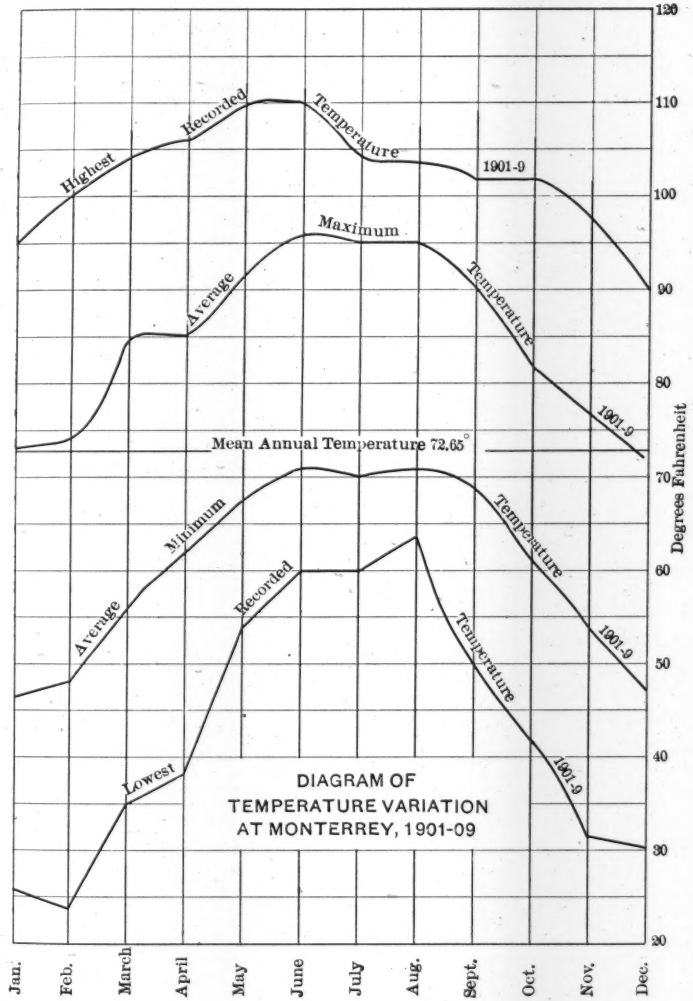

Highest Recorded Temperature
1901-9
Maximum Temperature
Average
1901-9
Mean Annual Temperature 72.65°
Minimum Temperature
Average
1901-9
Recorded Temperature
Lowest
1901-9
DIAGRAM OF
TEMPERATURE VARIATION
AT MONTERREY, 1901-09
Degrees Fahrenheit
120
110
100
90
80
70
60
50
40
30
20
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

FIG. 6.

thought desirable to obtain underflow supplies were (1) at the barrier of San Geronimo, and (2) at the Cañon of Santa Catarina, both shown on Plate II.

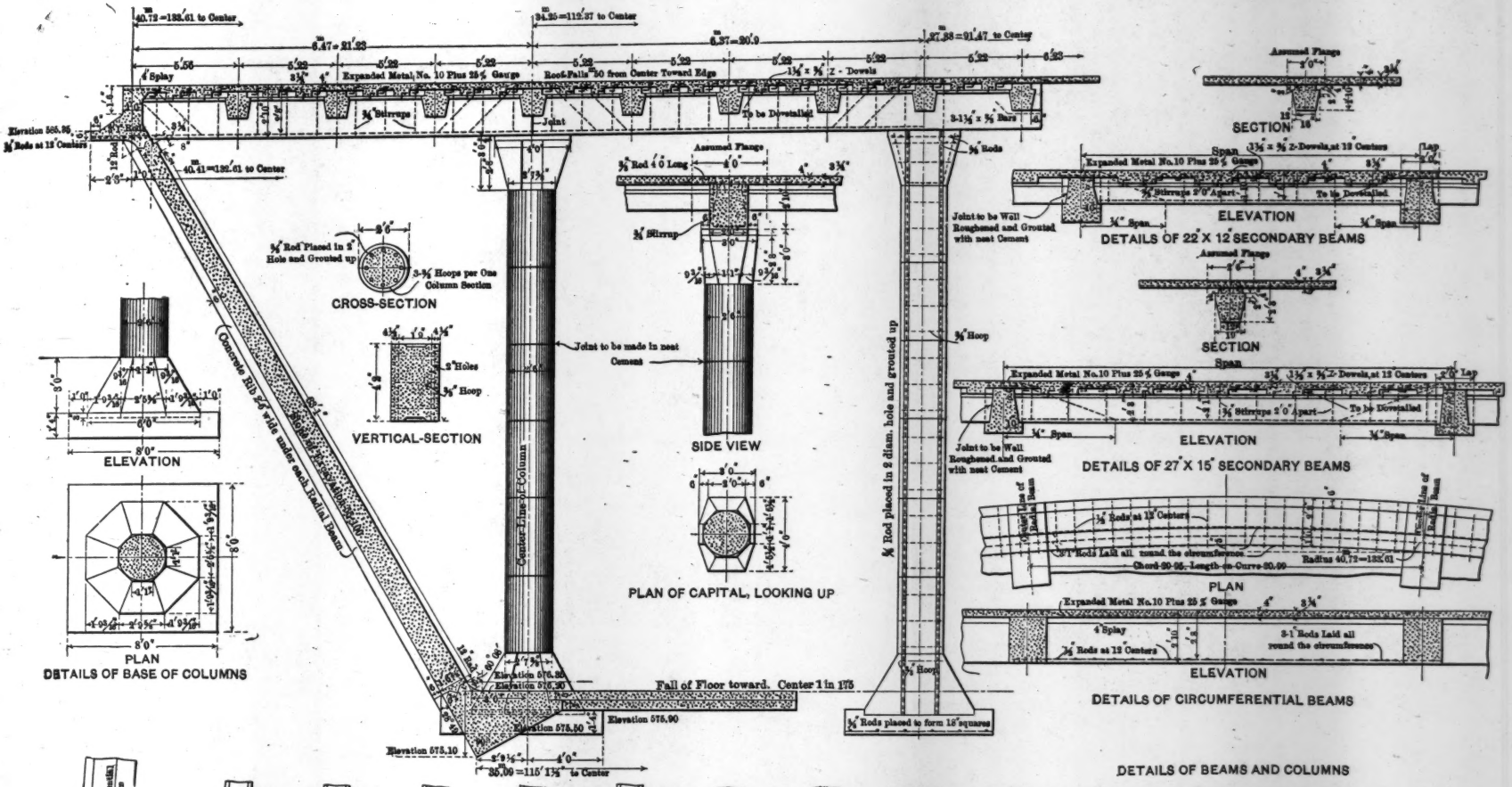
Conditions at San Geronimo, which is only 6½ km. west of Monterrey, were investigated by the State Government in 1892, to determine the depth of bed-rock, the rock on either side of the valley being shale, with its original bedding planes standing almost vertical. To determine this depth, borings were made by driving 2-in. tubes until it was assumed that bed-rock had been reached, a method which, in strata containing so many boulders, was obviously unreliable. These borings indicated that bed-rock was from 12 to 15 m. below the surface. If these had proved to be correct, there is no doubt that a development of the underground water at this point, by constructing a submerged dam combined with an infiltration gallery, would have yielded a large supply.

In March, 1906, the Company commenced operations at San Geronimo by sinking a well a few meters north of the then dry bed of the river. Water was found in considerable quantities a few meters below the surface, practically at the level of the river, that is, 570 m. above datum. This supply was used for provisional purposes, and will be referred to later in describing the San Geronimo gravity supply works.

Between August, 1906, and January, 1907, 4-in. bore-holes were sunk in the river bed and on the high ground to the north with a "Keystone" driller outfit. These borings showed bed-rock immediately under the river bed, at a depth of from 15 to 45 m., but dipping gradually as the borings were carried northward.

Boring operations were also carried on at Santa Catarina, during November and December, 1906, and in January, 1907, to determine the geological conditions, and the results are shown on Fig. 7. From the area of water-bearing gravels found, it was proposed to tap the underflow water at the 630-m. level by an infiltration gallery. This would have necessitated a gravitation tunnel 3 000 m. long, and an aqueduct of 14 km., which it was proposed to carry to one of two distributing reservoirs at Guadalupe, on the south side of the river, opposite Monterrey. In May, 1907, the writer, after making a study of all the available data which had been accumulated, had additional borings sunk farther across the valley to the north, and these revealed a considerable area of water-bearing gravels, and proved that, in former

PLATE VI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXII, No. 1193.
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



DETAILS OF BEAMS AND COLUMNS

FOR SOUTH RESERVOIR

geological times, the Santa Catarina flowed about 500 m. north of its present position, and to the back of Obispado Mountain, instead of through the city. This aspect of the subject was discussed with Mr. Schuyler, who agreed with the writer that, in the interest of economy, it was better to tap this supply by an infiltration gallery at the 560-m. level, and bring the water thus obtained to a reservoir to be placed at the western limits of the city, dividing the city, for distribution purposes, into two interchangeable systems, a high- and a low-pressure,

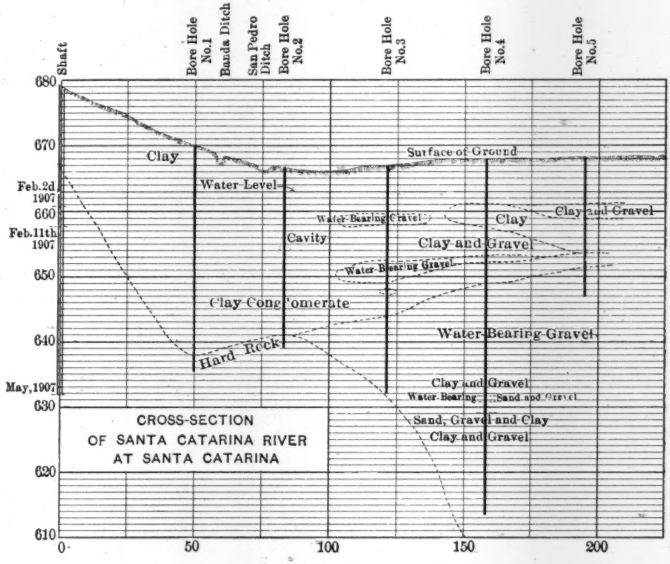


FIG. 7.

the high-pressure system being supplied from Estanzuela, 18 km. south of the city. One advantage to be gained from this change was that the scheme was capable of considerable extension, and any future developments at Santa Catarina Cañon would form part of the works to be constructed for both high- and low-pressure districts.

The future extension of the Santa Catarina sources, the writer believes, can be developed best by driving an infiltration gallery 10 m. below the surface of the Santa Catarina River, a little west of the village of the same name, and then conveying the water through a com-

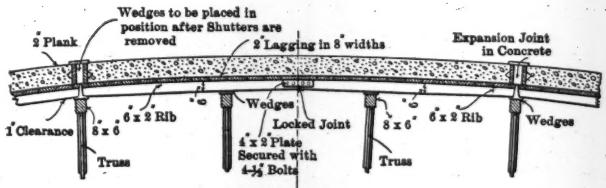
paratively short gravitation tunnel and pressure conduit to a main reservoir near San Geronimo having a top water level at an elevation of about 590 m. above datum.

Southern Sources of Supply.—The available sources of supply southward from Monterrey include a number of springs at various points in a distance of 40 km. Many of these springs are of uncertain quantity, and some are quite dry during periods of drought. The chief perennial springs near Monterrey are those which contribute to form the Estanzuela and Diente Rivers, both tributaries of the Silla, while farther south, at the Potrero Cerna, near El Porvenir, there are excellent springs, at a considerable elevation, with a minimum flow of from 170 to 200 liters (from 6 to 7 cu. ft.) per sec. The total quantity of water available from all these springs during the driest season would probably not be less than about 560 or 700 liters (from 20 to 25 cu. ft.) per sec.

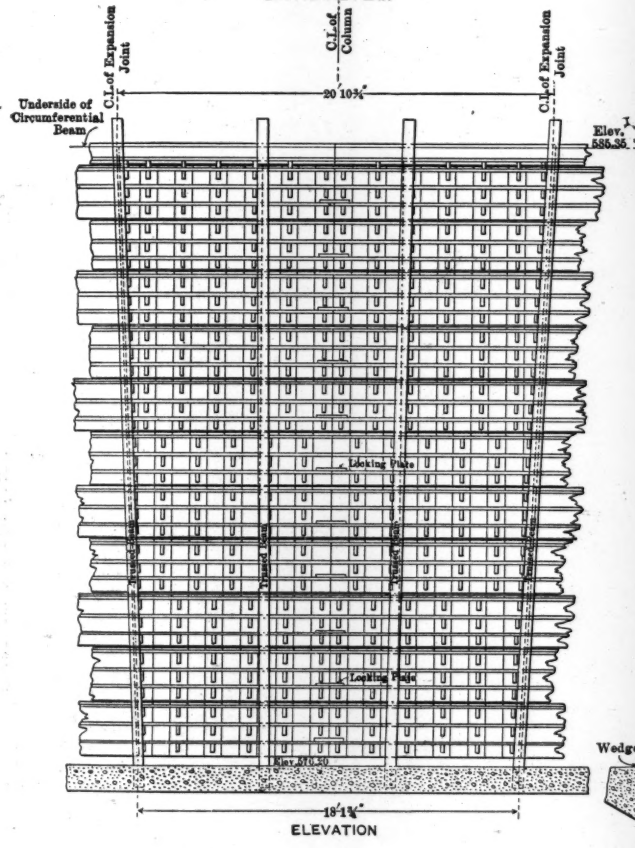
The Estanzuela springs issue at the foot of the Sierra Madre Mountains, and have a normal flow of from 56 to 85 liters (2 to 3 cu. ft.) per sec. in an ordinary dry year; they probably derive their water, through the limestone formation, from the neighboring water-shed of Santa Catarina, as the catchment area of the stream is only 910 hectares, and the stream has never been known to fail, even in the driest periods of prolonged drought. The rainfall on the area is about 30 in. per annum, and the catchment area is well wooded and covered with abundant vegetation. The El Diente springs have an ordinary dry-weather flow of about 28½ liters (1 cu. ft.) per sec.; but part of the water is carried underground, and the real quantity is much greater and could be developed by a small submerged dam carried down to bed-rock.

The elevation and the extreme purity of the water of the Estanzuela River made its acquisition very desirable, and the Company, therefore, purchased the Federal water rights owned by various members of the Estanzuela community, amounting to 91 liters per sec., and has since acquired a Federal concession to all the flood-waters of that river. It was decided, therefore, to adopt the Estanzuela River as the first step toward developing the water to the south of Monterrey for a high-pressure supply, the advantage of the scheme being that from time to time extensions could be made to tap other sources by gravity, as the demands of the city required. The Estanzuela scheme, there-

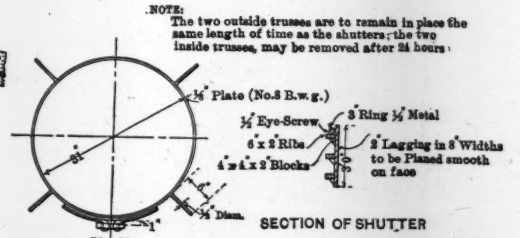
PLATE VII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXII, No. 1193.
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



SECTIONAL PLAN



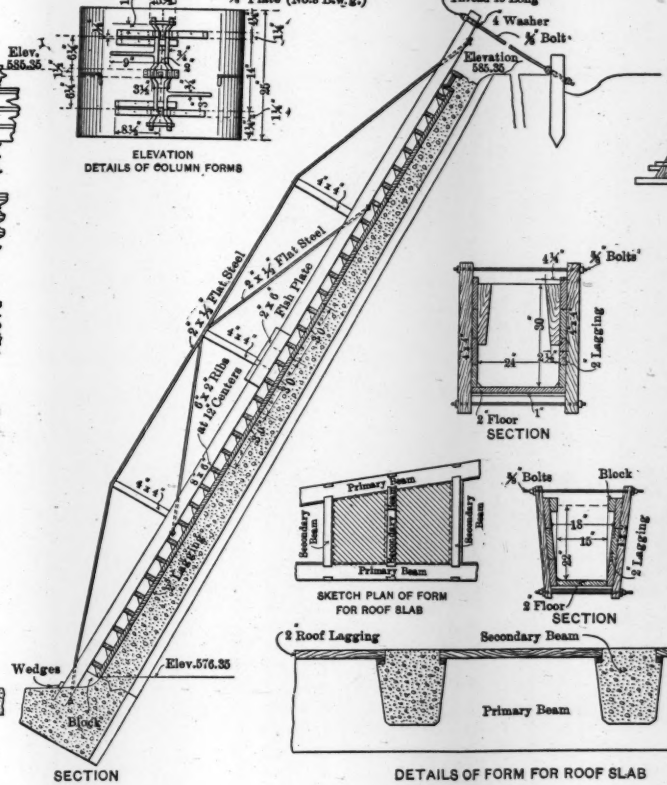
ELEVATION



SECTION OF SHUTTER

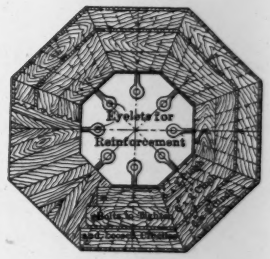
PLAN

ELEVATION
DETAILS OF COLUMN FORMS

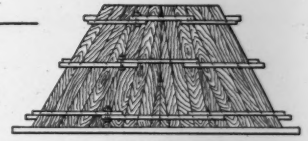


SECTION

PEDESTALS

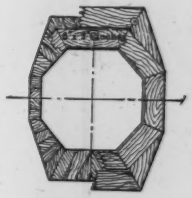


PLAN

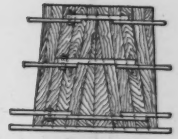


ELEVATION

CAPITALS



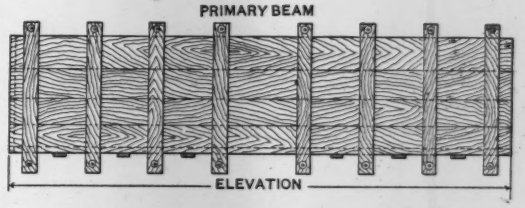
PLAN



ELEVATION

SECTION

PRIMARY BEAM

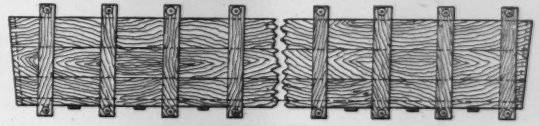


ELEVATION

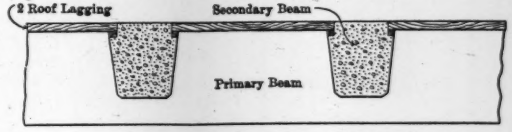
SKETCH PLAN OF FORM FOR ROOF SLAB

SECTION

SECONDARY BEAMS



ELEVATION



DETAILS OF FORM FOR ROOF SLAB

DETAILS OF FORMS FOR SOUTH RESERVOIR

fore, is a preliminary step toward future extensions which will be necessary in this direction as the city grows. The springs near El Porvenir, and others which contribute to the San Juan River, can be tapped at a sufficiently high level to convey them by a gravity pressure line to the Estanzuela Aqueduct near Mederos.

The two sources definitely decided on in July, 1907, were those from Estanzuela and San Geronimo. The works were designed to supply 40 000 000 liters daily, which it was assumed would be sufficient for all future developments for a population of 200 000 at a per capita consumption of 200 liters per day. The present requirements of the city's population, assuming that all the water was supplied by the Company, would be, at that rate, which is a very liberal one, only 18 000 000 liters daily. This, it was thought, would be easily met by the San Geronimo source alone, as it was estimated that it would provide not less than 20 000 000 liters, if the infiltration gallery was driven far enough into the water-bearing gravels.

The question of a high-pressure water supply for domestic use in a city like Monterrey is not a serious one, as practically nine-tenths of the houses are of one story. The increase in the number of large commercial buildings, however, will make the demand greater in the future, and this point has been kept in mind in arranging the division of the distribution systems.

Materials for Concrete.

Cement.—In the early stages of construction the cement for the work was obtained from the Associated Portland Cement Manufacturers, Limited, of London, which supplied the "Pyramid" brand, from the Knight, Bevan, and Sturges Works, but later the supply was obtained from a new factory at Hidalgo, near Monterrey. The total quantity of Portland cement used was 42 500 bbl. of "Pyramid" and 32 500 bbl. of "Hidalgo." The English cement was tested for the Water-Works Company in London before shipment and again at Monterrey, to conform to the British Standard Specifications; the "Hidalgo" cement was required to pass the Standard Specifications advocated by the Special Committee of the American Society of Civil Engineers. The quality in each case was of the very highest, no difficulties being experienced at any time.

Sand and Rock.—One of the chief difficulties in connection with the construction work in its initial stages was in procuring satisfactory sand for the concrete. An investigation of the quality of all the available sands in the neighborhood of Monterrey resulted in the decision to use a manufactured sand obtained from the calcareous shales in the foot-hills opposite the city, on the south side, and near the site of one of the proposed reservoirs. A quarry was opened, and the raw material was delivered by a gravity plane to a crushing plant, 230 m. from the quarry and at a level about 50 m. lower.

The plant consisted of a No. 5 Austin gyratory rock-crusher, fitted with elevators and revolving screens of various dimensions, driven by a 150-h.p. Erie steam engine; two sets of Traylor's heavy-duty crushing rolls, one having 30 by 16-in. and the other 18 by 12-in. rolls; and a Niagara sand disintegrator. This plant, except during a short period when the requirements were beyond its capacity, was able to produce all the sand and rock required for construction purposes. More than 40 000 tons of rock were quarried, the greater part of which was converted into crushed stone and sand.

Table 2 gives the chemical analysis of the chief constituents of the various sands examined.

TABLE 2.—Analysis of Sands in the Neighborhood of Monterrey.

No.	Location.	Percentage of silica (absolute). SiO_2	Percentage of alumina, Al_2O_3	Percentage of sesqui-oxide, Fe_2O_3	Percentage of lime carbonate, $CaCO_3$
1..	Arroyo Seco, near brickyard at Monterrey	60.10	17.95	2.89	8.01
2..	Arroyo Seco, near brickyard at Monterrey, No. 2	42.92	14.26	4.66	34.58
3..	Near García Station, Mexican National R. R., Chiquito River, No. 1	50.22	9.72	1.44	34.62
4..	Near García Station, Mexican National R. R., Chiquito River, No. 2	48.7	4.92	8.28	35.43
5..	San Luis Potosí	85.02	5.00	7.38	2.21
6..	Topo Grande, Pesquería River	40.20	5.15	4.25	46.50
7..	Hornos, near Torreón	77.9	13.1	2.4	4.9
8..	Salinas River, at Salinas	41.5	5.7	1.4	48.2
9..	Pits near Caballeros, on Tampico Branch of Mexican Central R. R.	73.4	5.6	4.4	10.1
10..	Santa Catarina River, near San Geronimo (washed sand)	12.40	2.06	1.14	81.70
11..	Santa Catarina River, at Monterrey	17.4	2.50	2.00	77.00
12..	Composition of rock, quarry in foot-hills opposite Monterrey, Monterrey Water-Works and Sewer Company's property	40.44	15.70	2.20	34.30
13..	Manufactured sand from above quarry (run of crusher)	51.80	12.14	3.7	32.6

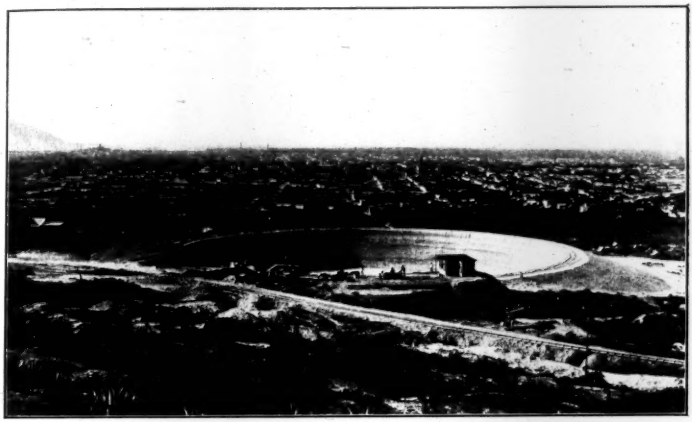


FIG. 1.—GENERAL VIEW OF EXCAVATION AND EMBANKMENT FOR SOUTH RESERVOIR BEFORE LINING.

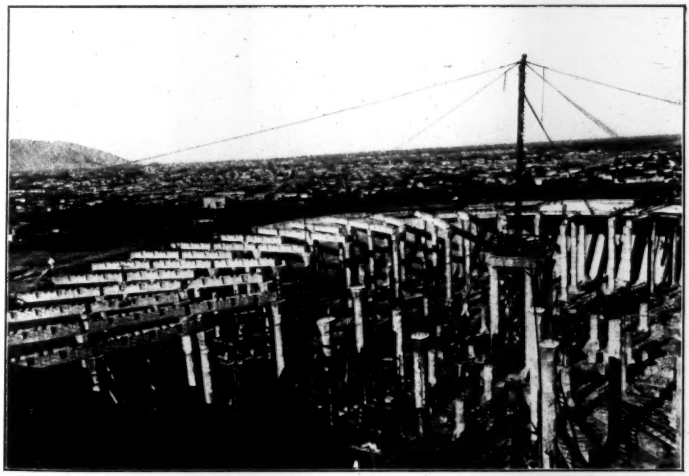


FIG. 2.—VIEW OF WESTERN HALF OF SOUTH RESERVOIR, SHOWING FINAL SETTING UP OF DERRICK ON CENTRAL COLUMNS.

The chief sands used for ordinary building purposes in Monterrey are Nos. 10 and 11, which are procured from the bed of the Santa Catarina River. As these sands contain large proportions of lime carbonates, which make them very undesirable for important structures, their use was limited to relatively unimportant work. The best sands procurable were Nos. 5 and 9, but the long distance of the pits from Monterrey, and consequently the heavy freight rate, made their use prohibitive on economical grounds. The best of the available sands, although it was very fine, was No. 7, from Hornos, near Torreon, as it could be depended on for uniformity and could be obtained f. o. b. cars at Monterrey for 3.18* pesos per ton.

The bulk of the sand and crushed rock used was similar to Nos. 12 and 13, and reference to the cement sand tests in Table 3, will show that the manufactured sands gave very satisfactory results.

Table 3 gives the average tests made with the "Hidalgo" cement and various sands, alone and in combination, for the purpose of obtaining comparative results; the mixtures tested were composed of 3 parts of sand to 1 of cement.

TABLE 3.—TESTS OF "HIDALGO" CEMENT WITH VARIOUS SANDS.

Sand.	At 7 days.	At 28 days.
Ottawa (Standard)	305 lb.	414 lb.
Monterrey, 1½ parts, Hornos, 1½ parts	188 "	313 "
Monterrey	253 "	365 "
Hornos	202 "	301 "
Manufactured sand, Company's crusher	372 "	566 "
Hornos, 2 parts, Crusher sand, 1 part	231 "	352 "
Hornos, 1½ parts, Crusher sand, 1½ parts	265 "	346 "
Hornos, 1 part, Crusher sand, 2 parts	248 "	328 "

The Hornos sand was used during a few weeks in the latter part of 1908, when the crusher was unable to produce all that was required. Its use was restricted to thick walls which were required to be watertight, and it was always used in equal proportions with the crusher dust.

*All costs given in this paper are in Mexican pesos, one peso being equivalent to 50 cents in U. S. currency.

Estanzuela Supply.

Intake Works.—The intake (Fig. 8) is about 1 km. below the lowest spring and at a point where the maximum flow of the stream was observed. The works consist of a small monolithic concrete dam, placed obliquely across the stream at an angle selected for the purpose of obtaining a foundation running parallel to the direction of the strata, which at this point were lying almost vertically across the bed of the stream. Above these strata the stream bed was formed chiefly of large cemented limestone blocks and smaller conglomerate. No storage being possible in this valley, which has a very precipitous fall, the height of the dam was fixed merely to obtain a small settling basin for sand and débris brought down in time of flood. The dam foundation was excavated to bed-rock, from which the upper disintegrated portions were carefully removed; the rock was then stepped, and dovetailed recesses were left for properly bonding the concrete.

The dam is carried well into the banks. Its extreme length is 52 m., its maximum height 4.50 m., and its greatest thickness 2 m. The up-stream face has a batter of 1 in 12, and the down-stream face, 1 in 8. The top of the wall is 1 m. thick. For the discharge of flood-water there is a weir 10 m. long, and it was calculated that with a depth of 1 m. it would discharge about 400 times the ordinary flow, or about 23 000 liters per sec., but, in addition, the whole length of the dam (excluding that occupied by the gate-house) was arranged for the discharge of abnormal floods, one of which, on August 27th, reached the enormous quantity of 82 070 liters (2 900 cu. ft.) per sec., or 825 cu. ft. per sec. per sq. mile of drainage area, a remarkable run-off from so small an area as 910 hectares. The concrete forming the dam is a 1:3:5 mixture. The overflow sill is 692 m. above sea level. When the dam was completed it was filled to the overflow level, in order to test the water-tightness of the basin, which, when cleared, was found to be slightly fissured on the north side. The leakage was sufficient to cause a serious loss during periods of drought, and it was then decided to line the basin with concrete, so that the stream would enter it without being under a head greater than its own depth. The length of the basin, measured along the center line of the original stream surface, is 85 m., and its area is 1 100 sq. m. At its upper end it is merely a lined channel, 5 m. wide at the entrance. The floor of the basin has a fall of 4 m. The lining was formed in

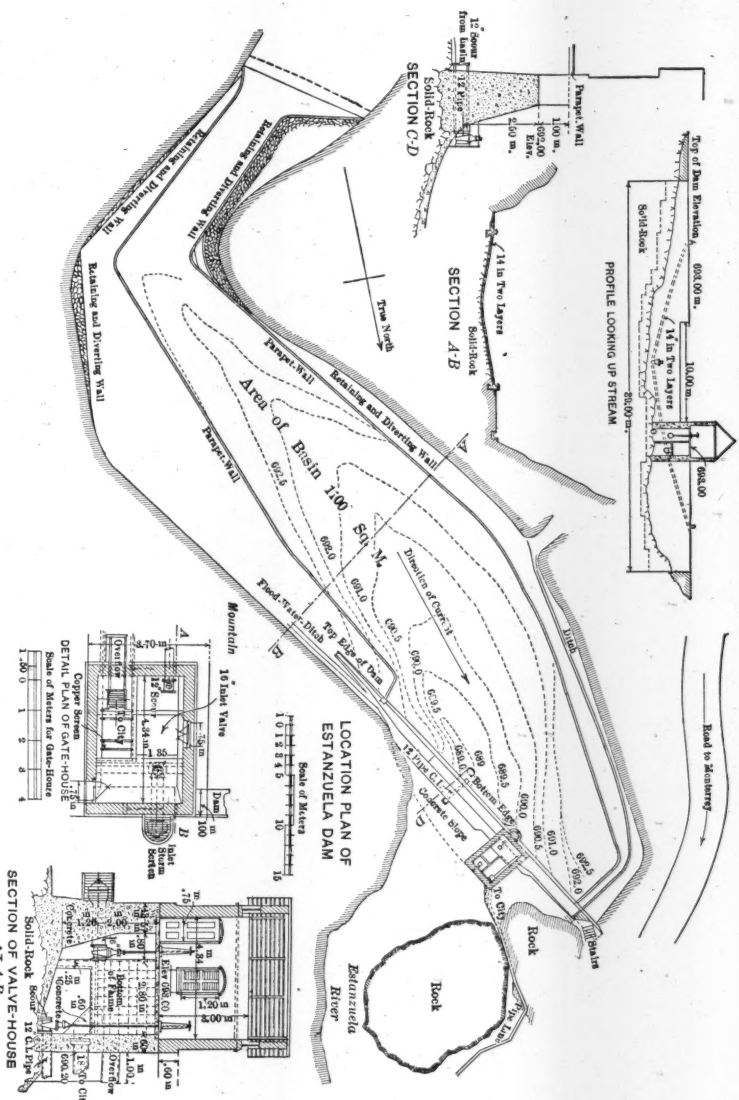

PROFILE LOOKING UP STREAM
Top of Dam Elevation
693.00 m.
10.00 m.
14 in Two Layers
Solid-Rock
693.00
SECTION A-B
14 in Two Layers
Solid-Rock
SECTION C-D
12" Scour from Basin
12" Pipe
Solid-Rock
Parapet-Wall
True North
Retaining and Diverting Wall
Area of Basin 1.00 Sq. M.
Direction of Current
Flood-Water-Ditch
Top Edge of Dam
Ditch
Road to Monterrey
Rock
Rock
Estanzuela River
Pipe Line
LOCATION PLAN OF ESTANZUELA DAM
Scale of Meters
Mountain
16" Inlet Valve
Dam
Inlet Storm Screen
Overflow
To City
Copper Screen
DETAIL PLAN OF GATE-HOUSE
Scale of Meters for Gate-House
SECTION OF VALVE-HOUSE AT A-B
Solid-Rock
Concrete
Bottom of Flame
Elev 693.00
12" C.I. Pipe
Overflow
To City

FIG. 8.

two thicknesses totaling 30.5 cm. (12 in.) of 1:2½:3½ concrete, laid in panels approximately 3 m. square, the upper panels breaking joint with those immediately below; in this way a very satisfactory and water-tight lining was obtained. A parapet wall, 45.7 cm. high, surrounds the basin. For scouring out the basin a 30.5-cm. (12-in.) cast-iron pipe was taken through the dam at the lowest point, this pipe being provided with a gate-valve encased in concrete on the down-stream face.

The gate-house was built in connection with the dam at the north end of the overflow weir, its inner dimensions being 4.34 by 2.80 m. The substructure, to the level of the dam, is of concrete founded on the solid rock, and the superstructure is of brick rendered with cement plaster. The roof is of framed timber with red French tiles.

The intake pipe is of cast iron, 40.6 cm. (16 in.) in internal diameter, fitted outside with a movable copper screen which is further protected by a wrought-iron hinged screen to prevent damage from stones, floating timber, etc., during times of flood. Inside the gate-house the outlet pipe is provided with a 40.6-cm. (16-in.) sluice-valve, operated from the floor level by a vertical head-stock with worm-gearing. The gate-house has a scour-out pipe (also operated by a head-stock) and duplicate copper screens fitted to iron frames. From this house the water is conveyed to the upper portion of the conduit, which is a 45.7-cm. (18-in.) cast-iron pipe.

Of the total area of land, 885 hectares (2 187 acres), owned by the company, 392 hectares (970 acres) have been fenced in, to prevent any contamination of the springs. This fence is formed of five lines of barbed wire protected with stout hog netting at the bottom, in order to prevent more particularly the entrance of goats, many thousands of which pasture in the adjoining mountains.

On the high ground immediately below the intake, a 3-roomed stone house has been constructed for the inspector in charge of the intake works, who also keeps in daily touch with the general office and records the condition of the stream, particulars of rainfall, etc.

Aqueduct.—The total length of the aqueduct, from the intake dam to the South Reservoir, is 18 700 m., made up as shown in Table 4.

The gradient of the concrete pipes is 0.43% from Estanzuela to Mederos, and 0.53% from Mederos to the South Reservoir. The calculated discharging capacity of the conduit when running full is 364

FIG. 1.—VIEW OF SEPARATELY MOULDED SECONDARY BEAMS IN YARD BELOW SOUTH RESERVOIR.

FIG. 2.—SETTING PRIMARY BEAMS, SOUTH RESERVOIR.

liters (13 cu. ft.) per sec. for the upper, and 465 liters (16.4 cu. ft.) per sec. for the lower section. For these pipes, the coefficient, *n*, in Kutter's formula, was taken at 0.013. At present the line has been limited by overflows to discharge three-quarters full.

TABLE 4.—ESTANZUELA AQUEDUCT.

Description.	Length, in meters
Cast-iron pipes, 45.7 cm. (18 in.) in diameter, along the stream bed of the Estanzuela River	110
Concrete tubes, 55.9 cm. (22 in.) in diameter, to Mederos (including 281 m. of tunnel)	4 473.81
Cast-iron siphons, 45.7 cm. (18 in.) in diameter: Calabozos.....239 m. South Virgen.124 " North Virgen.177 " Mederos.....426 "	966
Concrete tubes, 63.5 cm. (25 in.) in diameter, Mederos to South Reservoir.	12 089.19
Cast-iron siphons, 50.8 cm. (20 in.) in diameter: Necaxa.....315 m. San Augustin..796 "	1 111
Total	18 700

The increase in the size of the pipes from Mederos is for the purpose of receiving the waters of the Mederos River and other springs in the San Pablo and Aqua Verde catchment areas, as shown on Plate II.

The invert of the concrete conduit where it leaves the Estanzuela River is 684.25 m. above datum, and at the valve-house of the South Reservoir it is 589.00 m.

The concrete pipes were manufactured and laid under contract with Mr. Arthur S. Bent, of Los Angeles, Cal., the Company providing all materials, labor, etc. The contractor was paid 10 cents per lin. ft. of pipe manufactured and 10 cents per lin. ft. laid. He was also responsible for the satisfactory completion of the work.

Fig. 9 shows the details of the joint recommended by Mr. Schuyler and adopted for these pipes. The 63.5-cm. (25-in.) pipes were 61 cm. long and 76 mm. (3 in.) thick. The 55.9-cm. (22-in.) pipes were of the same length, but 70 mm. (2¾ in.) thick. For the purpose of strengthening these pipes while hauling them over very rough roads they were reinforced with four rings of No. 6 galvanized-iron wire.

Manufacture of Pipes.—The pipes were manufactured under the supervision of Mr. H. Stanley Bent, at a pipe yard established below

the crushing plant, from which the crushed rock and sand were delivered by gravity in bogies run on narrow-gauge rails. The area of the pipe yard was approximately 1¼ hectares, and it was laid out with parallel lines of 76-mm. (3-in.) galvanized-iron piping with hose couplings for sprinkling purposes. After trials with aggregates of various sizes, the concrete for the pipes was proportioned by volume as follows:

Crushed rock broken to pass through a 19-mm. screen	0.136 cu. m.
Manufactured sand (run of rolls)	0.119 " "
Portland cement	0.090 " "
Total	0.345 cu. m. = (12.2 cu. ft.)

The above quantity manufactured two 63.5-cm. pipes; a 55.9-cm. pipe required 0.1415 cu. m. (5 cu. ft.) of the material, in the same proportions. Fig. 9 shows the forms for these pipes, and Fig. 2, Plate III, illustrates the process of moulding. The forms consist of cast-iron bottom rings, to the proper section of the joint, and inner and outer steel forms of 3-mm. plate, provided with inner and outer locking arrangements. The concrete was poured through a cast-iron hopper which fitted to the top of the outer form.

The concrete, which was mixed very dry, in a ½-cu. yd. batch, "Smith" mixer, was thoroughly tamped with a 22-lb. tamper, and worked until it was of a stiff jelly-like consistency, the wire rings being added as the concrete was placed. The best results were obtained with the minimum quantity of water. The upper joint was moulded with a heavy cast-iron ring. The jacket and core forms were loosened immediately, and placed over other rings, a sufficient number of bottom rings being used for a day's work. For the pipes required for curves, special forms were used to give the necessary bevel to the joint. After 24 hours the finished pipes were lifted from the bottom ring with a special lifter, and ranged in position for coating internally with a Portland cement grout to which a little freshly slaked lime was added. The pipes were all numbered, and were kept moist for 10 days by constant sprinkling. They were not hauled to the work until 28 days after they were moulded, although this rule was sometimes broken, to the detriment of the pipes. More than 32 000 pipes were

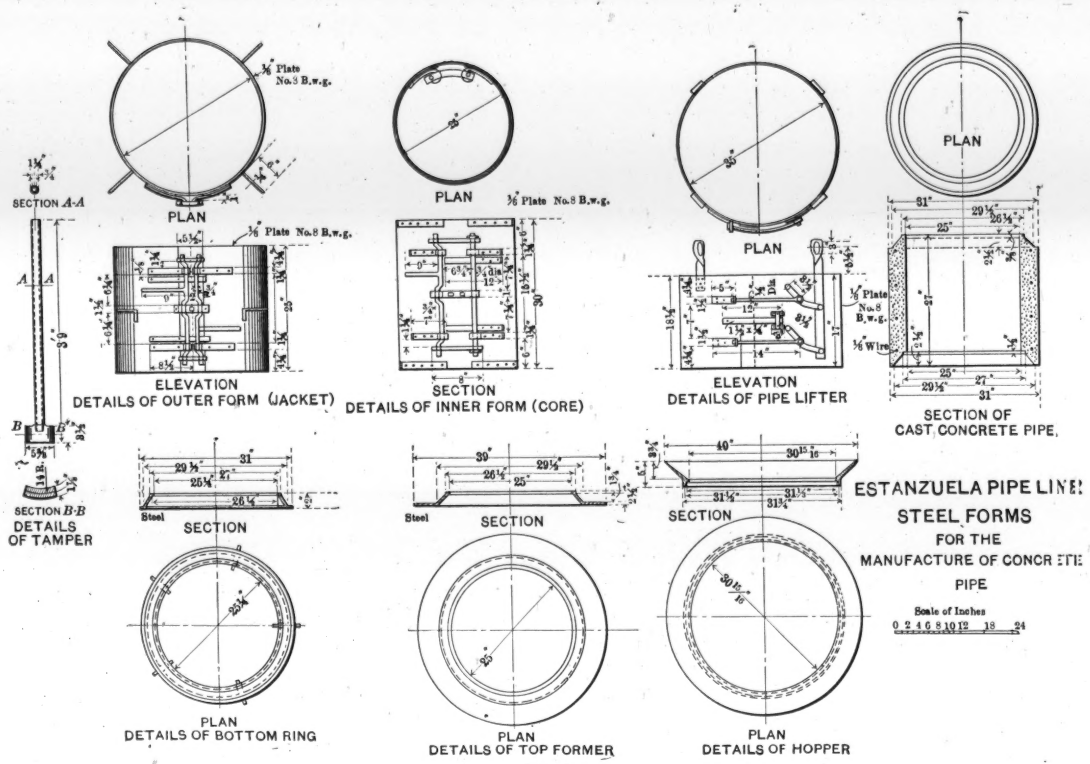

PLAN
SECTION A-A
ELEVATION
DETAILS OF OUTER FORM (JACKET)
PLAN
SECTION
DETAILS OF INNER FORM (CORE)
PLAN
ELEVATION
DETAILS OF PIPE LIFTER
PLAN
SECTION OF
CAST CONCRETE PIPE.
SECTION B-B
DETAILS
OF TAMPER
SECTION
PLAN
DETAILS OF BOTTOM RING
SECTION
PLAN
DETAILS OF TOP FORMER
SECTION
PLAN
DETAILS OF HOPPER
ESTANZUELA PIPE LINE
STEEL FORMS
FOR THE
MANUFACTURE OF CONCRETE
PIPE
Scale of Inches
0 2 4 6 8 10 12 18 24

FIG. 9.

manufactured, but some were used for purposes other than the Estanzuela Aqueduct.

Cost of Pipes.—The contractor brought with him experienced concrete pipe makers from California, and these were afterward assisted by Mexican labor. In a day two tampers could manufacture from 45 to 50 pipes of the larger (63.5-cm.), and from 55 to 60 of the smaller (55.9-cm.) size.

The cost varied from 2.75 to 3.25 pesos per pipe for the smaller, and from 3.50 to 4.00 pesos for the larger size.

The approximate cost of manufacturing is as follows: Taking, as a fair example, one week's work during March, 1908, the wages paid to the 74 men comprising the total pay-roll (though part of this labor was intermittent) amounted to 981 pesos. This includes a general foreman at 10 pesos per day, four American tampers at 7.50 pesos, and Mexican labor varying from 4 to 1 peso, and all labor necessary to handle and finish the pipes, including coating the interiors. During this week there were made 1 126 of the 63.5-cm. and 1 095 of the 55.9-cm. size. The pay-roll includes 520 pesos for the larger pipes (46 cents each) and 461 pesos for the smaller pipe (42 cents each). Table 5 shows the quantities and cost of the materials used in the manufacture of these pipes.

From Table 5 it is seen that the cost of the 63.5-cm. pipes was 3.37 pesos for material plus 0.46 peso for labor = 3.83 pesos per pipe, or 6.26 pesos per lin. m. (1.91 pesos per lin. ft.).

TABLE 5.—Cost of Concrete Pipe.

Materials.	For 1 126 pipes 63.5 cm. in diameter.		For 1 095 pipes 55.9 cm. in diameter.	
	Quantities.	Cost.	Quantities.	Cost.
Portland cement, at 8.00 pesos per bbl., delivered at pipe-making yard.	401 bbl.	3 208.00 pesos.	303 bbl.	2 424.00 pesos.
Sand, at 2.65 pesos per cu. m.	85 cu. m.	225.25 "	68 cu. m.	180.20 "
Crushed rock, 19-mm. (¾-in.), at 2.65 pesos per cu. m.	62 cu. m.	164.30 "	50 cu. m.	132.15 "
No. 6 galvanized-wire hoops, 4 rings to each pipe	4 504	203.00 "	4 380	183.00 "
Totals	.....	3 800.55 pesos.	.....	2 919.45 pesos.
Cost per pipe	.....	3.37 pesos.	.....	2.66 pesos.

FIG. 1.—VIEW OF COMPLETED SECTION OF SOUTH RESERVOIR. EXPANSION JOINTS IN SIDE-WALL NOT YET FILLED.

FIG. 2.—SETTING FORMS FOR SAN GERONIMO CULVERT.

The cost of the 55.9-cm. pipes amounted to 2.66 pesos for material plus 0.42 peso for labor = 3.08 pesos per pipe, or 5.05 pesos per lin. m. (1.54 pesos per lin. ft.).

The cost of cement included hauling from the bodega to the yard, a distance of about 5 km. At a later date, after the Company had commenced using the "Hidalgo" cement, some additional 55.9-cm. pipes were manufactured, so as to have them on hand as a reserve in case of emergency. In this work only Mexican labor was used, as the previous gang had been dispersed, but the tampers had had previous experience. Taking the cost of 418 pipes made during one period of 9 days, the detailed cost was as given in Table 6.

TABLE 6.—Cost of 55.9-Cm. Concrete Pipes.

Labor for 9 Days.		
Tampers, 2 at 4 pesos	72.00	Pesos.
Cement mixers (hand-mixing) and helpers, 6 at 1 peso	54.00	"
Water boy	4.50	"
Proportion of time of crusher foreman, one-third of 6 pesos, 2 pesos	18.00	"
Making 1 672 wire hoops, at 5 pesos per thousand	8.36	"
Man coating pipe, at 1 peso per day	5.00	"
Cost of labor making 418 pipes	161.86	Pesos.
Cost of labor per pipe	0.38	Peso.
Material.		
Cement, 118½ bbl., at 6.40 pesos per bbl., at pipe-making yard	758.40	Pesos.
Sand 24.6 cu. m., at 2.50 pesos per cu. m	61.50	"
Rock, 21.6 cu. m., at 2.00 pesos per cu. m	43.20	"
No. 6 wire, 3 362 lin. m	55.56	"
Lime	1.50	"
Cost of material for 418 pipes	920.16	Pesos.
Cost of material per pipe	2.20	"
Add cost of labor	0.38	"
Total cost per pipe for labor and material	2.58	Pesos.
Equivalent to 4.23 pesos per lin. m., or 1.29 pesos per lin. ft.		

Excavation for Pipe Line and Siphons.—The excavation for the pipe line and for bridge works, etc., was let by contract to Messrs. Scott and Lee, of Monterrey, under three classifications:

(1) "All material which in the judgment of the Engineer can be economically loosened with picks and handled with shovels."

(2) "Indurated earth or gravel, shale or rock which can be loosened without blasting, and 'sillar,' locally so-called, whether pure or mixed with other substances, and whether it requires blasting or not."

(3) "All rock not included in the above which requires drilling or blasting."

Locally, this classification is well understood, particularly No. 2, as it covers the sillar soils which are common in the neighborhood of

Monterrey. The contract prices were: No. 1, 50 cents; No. 2, 1.50 pesos; and No. 3, 2.50 pesos per cu. m. These prices were over and above the clearing and grubbing of the line, which was paid for at the rate of 100 pesos per hectare.

The route of the pipe line being along broken country, at some points difficult of access, service roadways, about 3 m. wide, for hauling material were constructed, and, for about 7 km., a roadway was made along the line of the trench.

The prices for the roadway, under the above classification, were: For No. 1, 35 cents; No. 2, 1.50 pesos; and No. 3, 2.50 pesos per cu. m.

The trenches were excavated 5 cm. below the required finishing depth, to allow for grading the pipes in selected material, and were taken out to an average width of 40 cm. greater than the outside diameter of the pipe, to allow for their proper jointing, and also to give sufficient room to roll the pipes in the trenches.

The final quantities of excavation were:

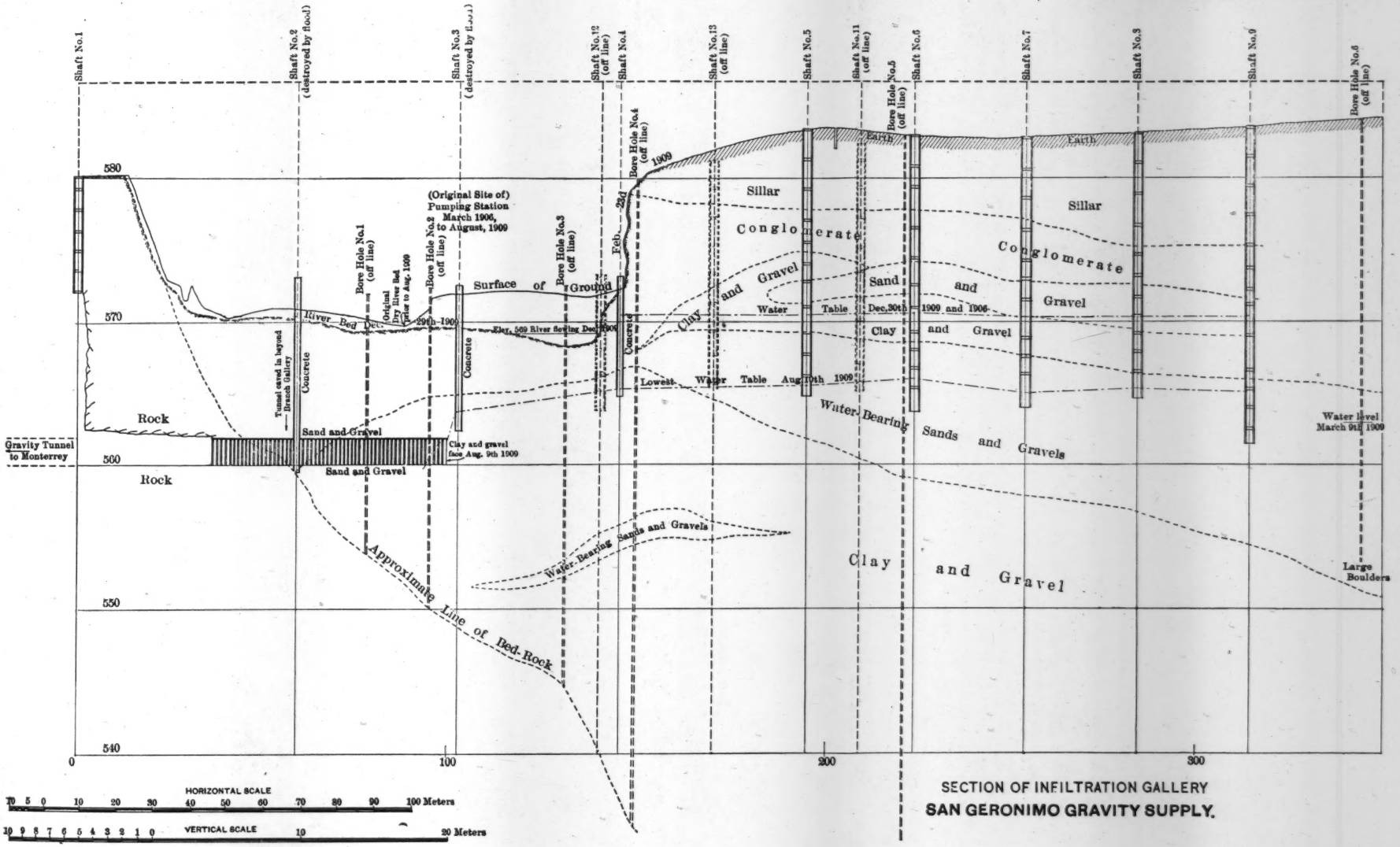
TRENCH:	No. 1	11 115 cu. m.
	No. 2	18 096 " "
	No. 3	6 650 " "
	Total	35 861 cu. m.
ROADWAYS:	No. 1	4 165 cu. m.
	No. 2	1 999 " "
	No. 3	30 " "
	Total	6 194 cu. m.

The route of the pipe line was laid out so as to obtain an average fill of not more than 1 m. over the tops of the pipes, but in some cases the cuts, for short lengths, were 3 m. deep. The excavation for this work began in June, 1907.

Hauling Pipes.—The pipes were hauled to the site of the work with ox-carts and mule teams. The cost of hauling varied from 25 cents per pipe at the lower end, to 1 peso per pipe at the upper and, comparatively speaking, inaccessible portion of the line. The weight of each 55.9-cm. pipe was about 182 kg.; that of each 63.5-cm. pipe was about 216 kg.

The breakages in all the pipes cast at the pipe yard amounted to about 1%, due chiefly to unloading them carelessly near the pipe line.

PLATE XI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXII, No. 1193.
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



SECTION OF INFILTRATION GALLERY
SAN GERONIMO GRAVITY SUPPLY.

Pipe Laying.—The pipe-laying gang was composed of 7 Mexicans under the direction of an American foreman, who was in charge of several gangs. One gang could lay daily from 60 to 73 m. (from 100 to 120 pipes). The following was the ordinary pay-roll for one gang:

1 Foreman at 8 pesos (proportion).....	2.00	pesos.
1 Pipe layer at 3 pesos.....	3.00	"
1 Pipe layer's assistant at 2 pesos.....	2.00	"
1 Cement mixer at 2 pesos.....	2.00	"
2 Outside plasterers at 2.50 pesos.....	5.00	"
2 Inside plasterers at 2.25 pesos.....	4.50	"
1 Water boy at 0.50 peso.....	0.50	"
Total.....	20.00	pesos.

This brings the average cost of laying the pipes to 32.8 cents per lin. m.

The pipes were jointed with 1:2 cement mortar, the outer joint being rounded over both pipes for a width of 12½ cm. (5 in.) and a height of about 19 mm. (¾ in.). In making these joints the pipe layers wore rubber gloves. The joints were kept moist, and the trench was back-filled with fine, screened material to a depth of 10 cm. above the top of the pipe. Inside, the joints were carefully caulked with cement and rendered smooth, the plasterers working continuously along with the pipe layers, doing from 20 to 35 m. at a time. Water had to be conveyed to the trenches by barrels on burros, and during the dry season it was sometimes carried 5 or 6 km.

Bridges.—The line as laid out passed over many gulches and dry arroyos, and these were crossed with reinforced concrete bridges of varying spans and heights, two being shown on Plate IV.

These bridges were formed of continuous horizontal girders, 1.10 m. deep and 1 m. wide, with a cantilever overhang at the abutments, varying in length from 1 to 2 m., so as to avoid settlement between the pipes and the bridges. The bottom reinforcement consisted of from 2 to 6 twisted bars of mild steel, varying in different spans from 12.7 to 19 mm. (½ to ¾ in.) in diameter. The turned up bars were 28½ mm. (1⅛ in.) in diameter; they were placed on either side, carried over the upper part of the beams, and continued along the end for the

overhanging part of the girder. These bars, when not obtainable of the full length, were spliced with a lap of 1.2 m. with No. 6 galvanized-steel wire. The vertical stirrups were 4.7 by 25.4 mm. ($\frac{3}{16}$ by 1 in.), of mild steel; they were equally spaced 30.5 cm. (12 in.) apart, and carried all around the girders, lapping at the center about 15 cm. (6 in.), all the steel being carefully wired together before placing the concrete.

The general type of the piers and abutments is shown by Fig. 1, Plate IV, and varies in height with practically every bridge, the foundations in every case resting on hard rock. The concrete for the girders was a 1 : 2½ : 3½ mixture, the crushed stone used having all passed a mesh of 19 mm. ($\frac{3}{4}$ in.). The piers were of 1 : 3½ : 5½ concrete, and heavy "displacers" were embedded within them.

The concrete was placed after the pipes had been laid through the form by the pipe contractor, the joints being kept clear of the bottom to the required distance by small moulded concrete blocks. The tops of the girders were moulded to a slightly segmental form. The bridges were all kept watered for about 15 days, and the forms were not struck for 28 days after placing. At Station 13.4 the pipes were carried over a picturesque arroyo on an elliptical arched bridge (Fig. 2, Plate IV) of 11 m. clear span.

The abutments of all bridges were protected by rubble walls in cement mortar carried up 60 cm. above the tops of the girders.

The contract price for the concrete work of these bridges, the Company furnishing the steel and cement, was 14 pesos per cu. m., and for placing reinforcing steel 35 pesos per metric ton (2 204 lb.).

There are 49 single-span bridges, the larger spans being 9.10 m.; 8 two-span, and 11 three-span bridges, their total length, including the overhang, amounting to 870.50 m., or 4½% of the whole length of aqueduct.

Concrete Aprons.—At 76 points there were small depressions which did not necessitate the construction of bridges, and at these places the pipes were encased in blocks of concrete carried up the hillside in the form of an apron having small abutment walls from 1 to 2 m. apart. This also served to protect the pipes from scouring action during rainstorms. At the upper end of the line, near the intake, the pipe had to be protected by concrete continuously for a distance of about 300 m., in order to prevent damage from falling rocks.

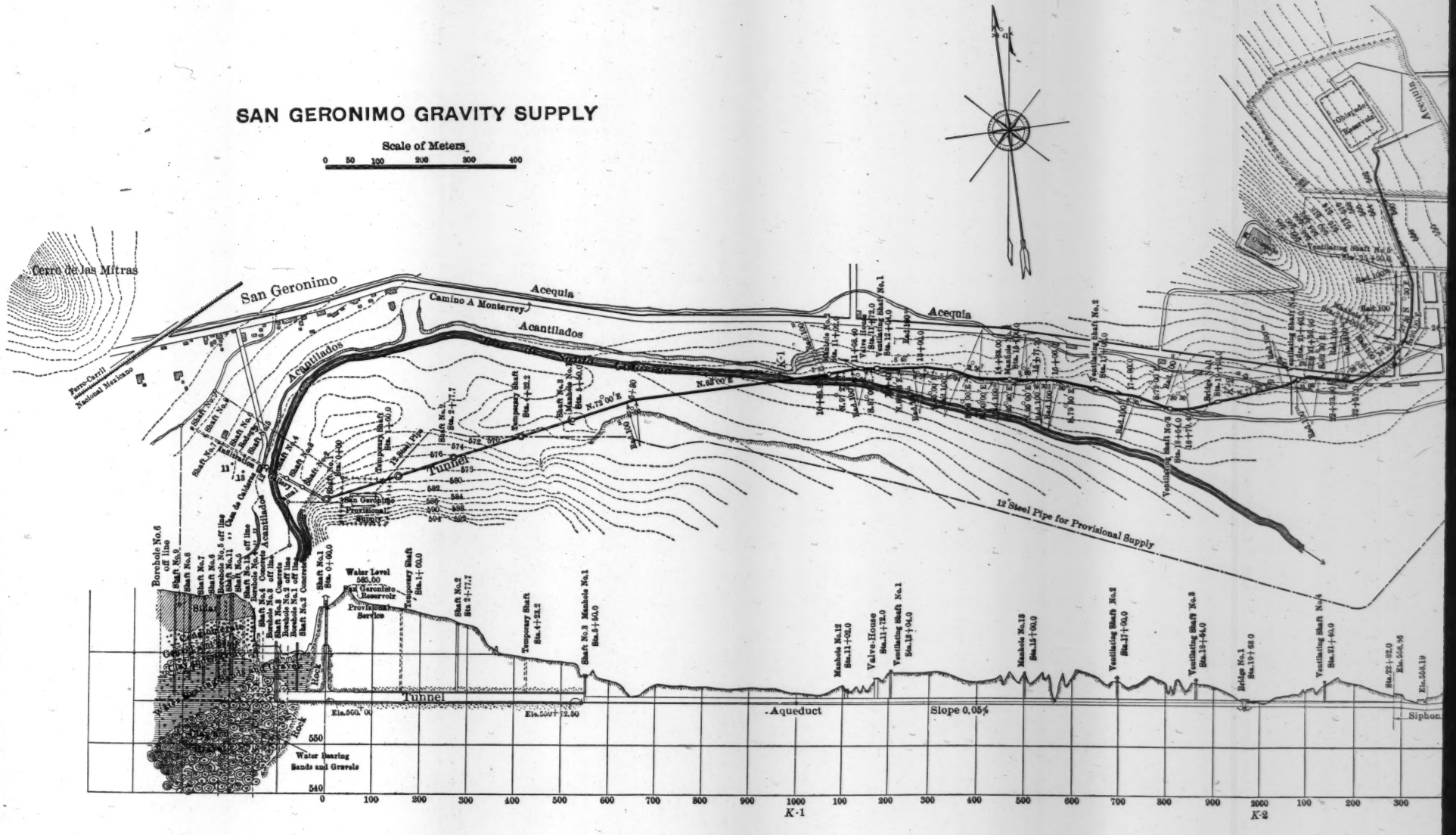

SAN GERONIMO GRAVITY SUPPLY
Scale of Meters
0 50 100 200 300 400
Cerro de las Mitras
San Geronimo
Acequia
Camino A Monterrey
Acantilados
Ferro-Carril Nacional Mexicano
Tunnel
12" Steel Pipe for Provisional Supply
Water Level 585.00 San Geronimo Reservoir
Provisional Service
Water Bearing Sands and Gravels
Aqueduct
Slope 0.05%
Siphon
Valve-House
Bridge No.1
K-1
K-2

PLATE XII.
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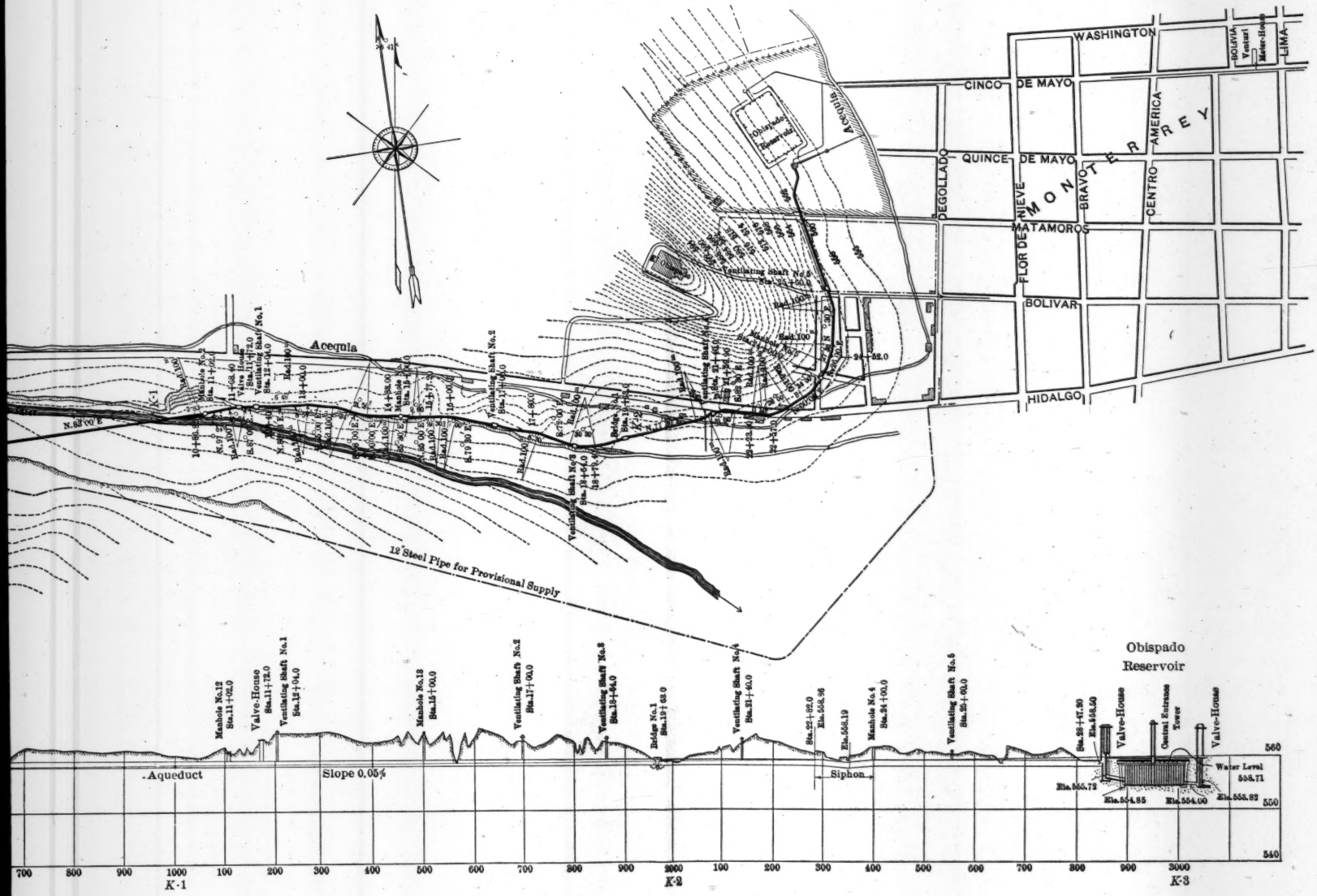

Ventilators and Manholes.—Along the route of the concrete pipe there are 27 ventilators, one of which, together with an entrance manhole, is shown by Fig. 1, Plate V. They consisted of simple concrete columns, 3.35 m. high, above the ground line, the interior of the shafts being formed of fire-clay pipes, 15 cm. (6 in.) in diameter. At each ventilator the pipe was cut and a block of concrete, the width of the trench, filled in as a foundation. Entrance manholes were also placed at 49 points, at 27 of which they immediately adjoined the ventilating columns.

Estanzuela Tunnel.—At 1 560 m. from the intake at Estanzuela, the conduit is laid through a tunnel 281 m. long. The tunnel was driven through hard calcareous strata from the open cuttings at each end. The inner dimensions were trimmed to approximately 2 m. high and 1½ m. wide. At the ends of the tunnel the rock was moderately easy to take out, but the inner section was very hard and difficult to blast. Ordinary hand drilling was adopted, and the actual cost of driving varied from 28 pesos per lin. m. at the ends to 50 pesos in the center.

The pipes were laid through the tunnel in the ordinary way, and back-filled from the center, so as to give a cover of about 45 cm. above to protect them from falling pieces of shale.

Siphons.—It has already been mentioned that there are 6 cast-iron pipe siphons. The head on these varies between 10 and 38 m. All are provided with special inlets and outlets, forming combined overflow and ventilating chambers, and have wooden hand-sluices to divert the water when necessary. The bottoms of all siphons are provided with 20-cm. cast-iron scour-out pipes, fitted with valves, and carried down to a lower point to obtain a free outlet. The valve-boxes are protected by being placed in heavy concrete chambers carried up above the level of ordinary floods.

The siphons are formed of cast-iron socket pipes, 3.65 m. (12 ft.) long, caulked in the ordinary way with lead joints. The thickness of the 45.7-cm. (18-in.) pipes is 19 mm.; that of the 50.8-cm. pipes is 21 mm. On the steep hillsides the pipes are anchored securely to the rock in concrete blocks reinforced with heavy iron chains. In some cases these siphons were difficult of access, but ox-teams hauled the pipes in a very efficient and satisfactory manner.

Overflow Chambers.—The ordinary overflows, of which there are 14, are similar in design to the siphon inlets.

Testing, etc.—When the line was completed it was tested for water-tightness, and the loss was found to be about 5%, part of which was probably due to absorption. At a later date it was found that the waters of the Estanzuela River, which contain 150 parts of calcium carbonate ($CaCO_3$) per million, deposited a very fine film of lime on the interior of the pipes, completely filling any pores there might have been. At the present time there is no measurable leakage, thus proving that the character of the work is very satisfactory.

The water was turned into the conduit on June 11th, 1908, and delivered to the city on the following day through a by-pass, before the reservoir was completed.

The pipe line is patrolled daily by an inspector with the authority of a gendarme, so as to prevent the unlawful abstraction of water, a very necessary precaution in so dry a country.

South Distributing Reservoir.

The distributing reservoir for the Estanzuela supply is at Guadalupe, on the foot-hills to the south of the Santa Catarina River, about 2 km. from the center of the city. The reservoir is a covered one, of reinforced concrete, and its capacity is 38 000 000 liters (10 000 000 U. S. gal.).

Excavation and Embankment.—The heavy slope of the ground at the selected site made the circular form the most desirable. On the low side the ground was excavated about 2 m. below the original ground line, while the excavation at the upper part of the slope was about 12 m. deep. The excavated material consisted chiefly of sillar and limestone conglomerate, which when broken up forms a calcareous clay of an excellent character for the formation of embankments, when proper care is taken. The dimensions fixed for the internal diameter of the finished concrete work of the reservoir were: 81 m. (265.68 ft.) at the top, and a depth of water of 9 m., with sides sloping 55 in 100.

Fig. 10 is a plan of the reservoir, with a cross-section of the excavation and embankment. On the lower side the original ground line was cut down in steps, and all loose earth, roots, etc., were carefully removed. The floor of the reservoir was chiefly sillar conglomerate, a hard material that required a considerable amount of blasting for its removal. The embankments were formed in 10-cm. layers

PLATE XIII.
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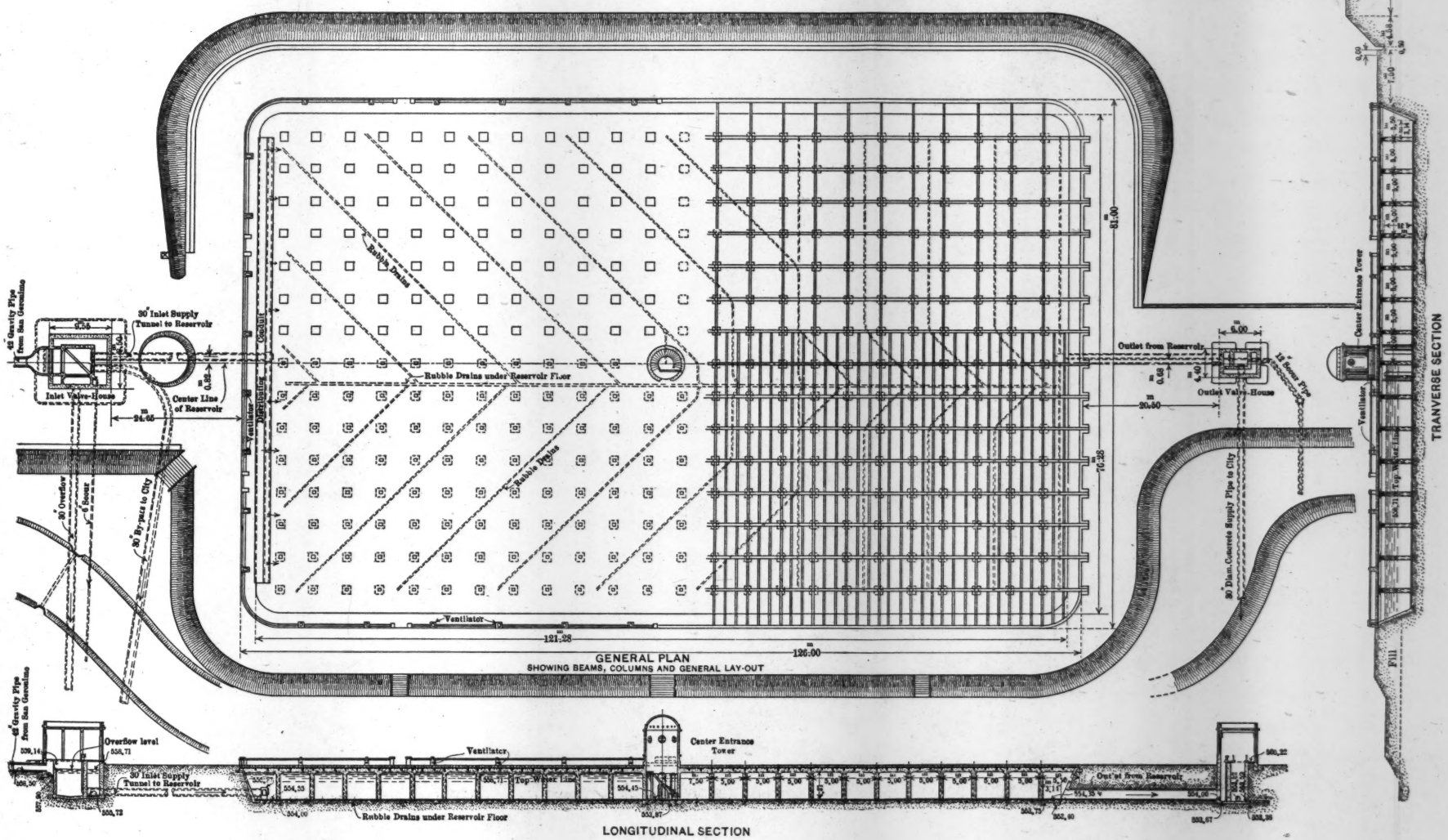
GENERAL PLAN AND SECTIONS, OBISPADO RESERVOIR

Scale of Meters

0 5 10 20 30 m



of sillar and conglomerate broken into small fragments and then rolled with 3-ton sectional rollers drawn by teams of 4 and 6 mules, which assisted in disintegrating the mass thoroughly, and produced by constant wetting a homogeneous and compact clay. The excava-

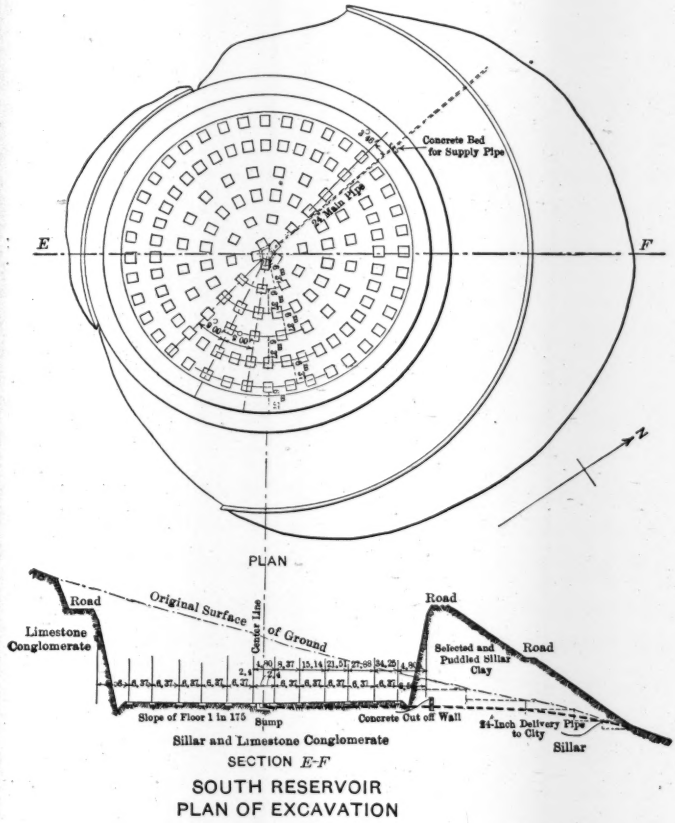


FIG. 10.

tion and embankment were left so that 15 cm. of trimming could be done at a later date, immediately prior to the lining of the reservoir. The excavated material amounted to about 34 000 cu. m., and, of this quantity, 31 500 cu. m. were used to form the embankment; the

remainder was taken to a spoil bank immediately adjoining, the black earth stripping being separated and reserved for covering the reservoir, etc. The contract prices for the excavated material placed in the embankment were:

	Pesos per cubic meter
Class 1.—Material which could be removed by plows and scrapers	0.60
Class 2.—This consisted chiefly of "sillar"	1.09
Class 3.—Limestone conglomerate (requiring blasting)	1.65

The prices (for the same classification) for material taken to the spoil bank, were 0.40, 0.80, and 1.40 pesos, respectively. Of the material taken out, 15% came under No. 1 classification, 80% under No. 2, and 5% under No. 3.

The excavation was begun at the end of May, 1907, and completed in January, 1908, by Scott and Lee, the contractors. The embankments were then allowed to stand until the beginning of July, 1908, to permit the whole to become thoroughly settled and consolidated prior to beginning the lining. In July the work of trimming the embankments and excavating for the foundations of the reservoir columns was commenced, under the Company's own administration, which completed the entire work.

Concrete Lining and Roof.—The general arrangement and details of the side-walls, columns, and roof are shown on Plates VI to IX. The principal feature consists in dividing the reservoir into radial sections and supporting the roof on 135 primary and 670 secondary beams, from 135 columns, spaced as follows:

Outer ring,	at	34.25	m.	from	center	40	columns.
2d	"	27.88	"	"		40	"
3d	"	21.51	"	"		20	"
4th	"	15.41	"	"		20	"
5th	"	8.77	"	"		10	"
6th	"	2.40	"	"		5	"
Total						135	columns.

The inner bottom diameter of the reservoir is 70.32 m. (230.64 ft.); the upper inside diameter is 81 m. (265.68 ft.); the water depth at the overflow level is 9 m. (29½ ft.).

PLATE XIV.
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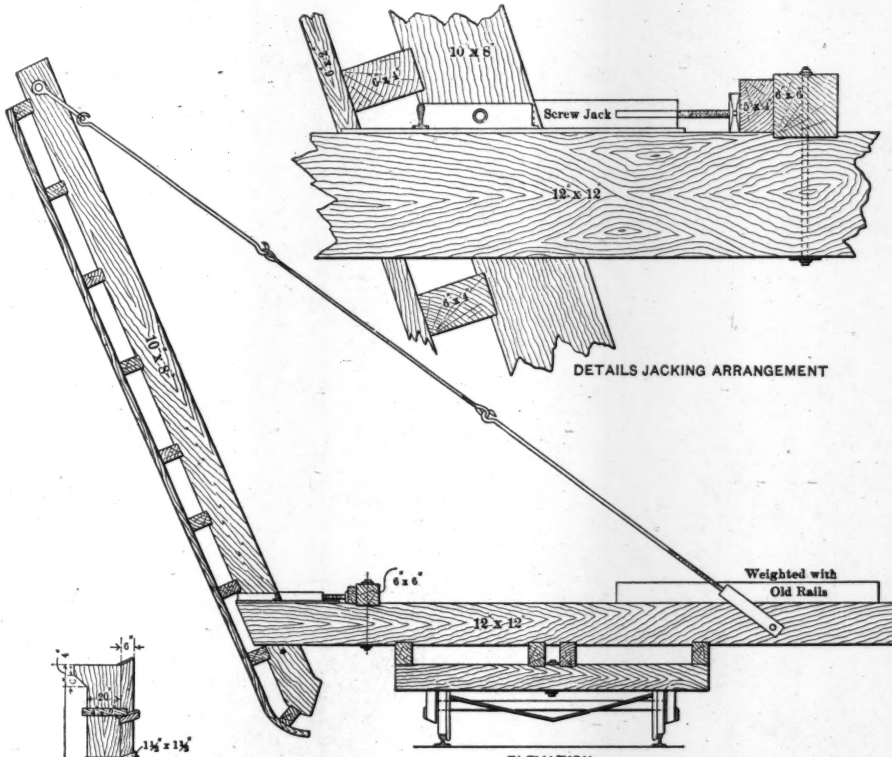
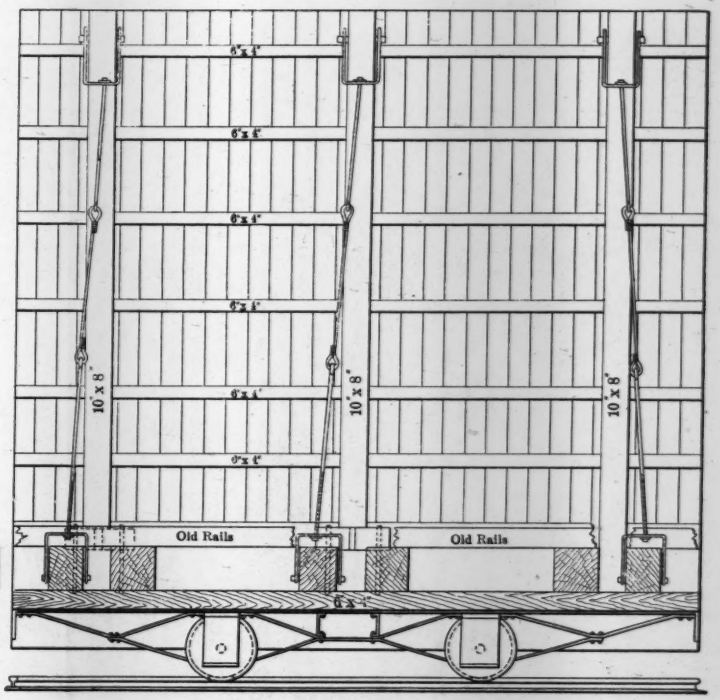
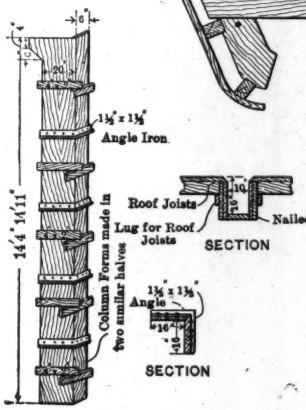


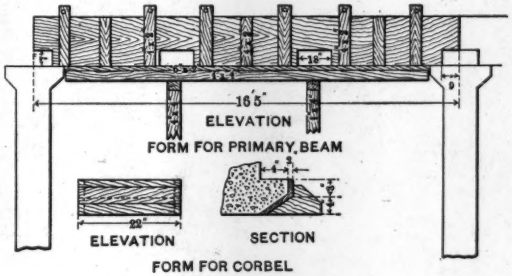
DETAILS JACKING ARRANGEMENT

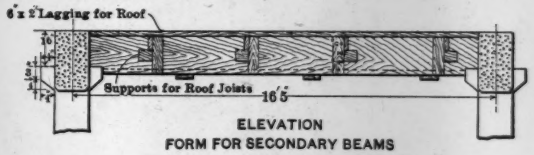
ELEVATION
FORM FOR WALL





ELEVATION OF COLUMN FORM





DETAILS OF FORMS FOR CONCRETE WORK OBISPADO RESERVOIR

The roof was designed to carry a dead load (the earth cover) of 150 lb. per sq. ft., and a live load of 100 lb. The maximum compressive fiber stress in the concrete was assumed at 550 lb. per sq. in. for the beams, and at 350 lb. for the columns, a low figure, because of their eccentric loading. The tensile strength of the steel was taken at 14 500 and 16 000 lb. per sq. in. The twisted steel used for the column reinforcement was made at the local steel plant, but for the beams, etc., a twisted lug bar, of higher quality and greater permissible tensile stress, was used. The total quantity of steel used was 178 tons. It was calculated that the load on the column foundations would not exceed 1¼ tons per sq. ft. With the exception of the side-wall and floor, all the concrete was reinforced with steel, of the sizes and spacing shown on Plate VI.

General Construction and Erection Scheme.—The question of ordinary forms, requiring very heavy timber work, was a serious one, as suitable lumber is very expensive in Mexico; and the necessity of finishing this reservoir before the end of the first term allowed under the concession, which expired on December 31st, 1908, led to the adoption of what the writer believes is an original scheme for so large a structure. This scheme was to cast the columns in short sections, mould the radial and secondary beams as separate members, and then place them in position with derricks. At the same time, in the case of the beams, it was important not to sacrifice either the benefit of that part of the slab which is ordinarily assumed to act as a part of the beam, or the additional strength due to continuity; and, in case of the columns, the strength due to the reinforcement extending from the foundation to the beams.

The T-beam section was secured by notching the tops of the moulded members, with notches 10 cm. deep, throughout the lengths of the beams, as shown on Plate VI. A computation of the maximum flange increment shows that these notches are sufficient to transfer the flange stresses to the stem, but, for additional security, flat steel bars were bent to a Z-shape and embedded in the top of the beam, about 60 cm. apart. Continuity in the beams was secured by carrying the steel to the tops of the beams over all supports, and, after erection, concreting them into the roof slab. The secondary beams, after casting, were dropped into recesses left in the radial beams for the purpose.

Concreting, Mixing, etc.—The radial beams and column sections were cast as nearly as possible under their ultimate positions; the secondary beams were cast outside and immediately adjoining the reservoir.

The rock and sand was brought from the Company's crushing plant, in 3-cu. yd., side-dump cars, running on a 30-in. track by gravity a distance of 1 km., the last 150 m. requiring hauling with 6 mules. The cars returned all the way to the crusher by gravity. These cars dumped the material into bins on the high ground above the reservoir; from there it was hoppered into cars which carried to the mixer all the material for one batch of concrete. Two No. 1 Smith mixers were used, and from 25 to 30 batches per hour could be handled in each machine.

The concrete was transported from the mixers to place in ½-cu. yd., 18-in. gauge, swivel, steel dump-cars pushed by two men. All the concrete used in the bottom of the reservoir, for the main beams, columns, and floor, amounting to about 2 460 cu. m., was dumped through a chute into smaller cars. The chute had so many baffle-plates and bolts that it resembled a gravity mixer, but, although it was 12 m. long, it effectively prevented the separation of the materials.

Concrete Placing and Moulding.—The square foundations for the columns were deposited *in situ*, a recess being left for the reception of the pedestals, which were moulded in place afterward. The capitals and pedestals were cast in one piece, and the columns in 1.21-m. (48-in.) sections, eight 5-cm. holes being left in them by using wrought-iron pipes, held in place by templates and removed when the castings were about 3 hours old. The columns were erected by threading them on the 15.8-mm. (⅝-in.) reinforcing rods, which extended from the pedestals up through the capitals. The rods were in two lengths, arranged to lap alternately at one-fourth, the center, and three-fourths of the height of the columns. In erection, a light timber frame was used in conjunction with the derrick, and, as the columns were placed, the reinforcing steel was grouted solid with 1:2 cement mortar.

All the erection was done with a combined stiff-leg or guy derrick, having an 80-ft. boom and a 50-ft. mast, and fitted with a 30-h.p. Lambert hoisting engine. The derrick was erected seven times at the circumference, and its final position was on top of the center columns. The moving of the derrick a distance of about 45 m. and its subse-

FIG. 1.—CONSTRUCTION OF WEST SIDE-WALL OF OBISPADO RESERVOIR.

FIG. 2.—PRIMARY BEAMS AND COLUMNS, OBISPADO RESERVOIR.

quent erection occupied usually about 48 hours. The erection work was carried on continuously, day and night, the placing of the whole of the radial and secondary beams and columns occupying 2½ months.

Forms.—As the erection scheme was designed to reduce the cost of forms, economical construction was of considerable importance. The wall was formed in 40 panels, about 6 m. wide and 11.27 m. high. The chief object in arranging them in this manner was to permit an expansion joint, 30 cm. wide, at each panel; this joint was not filled until after the completion of the roof, when the temperature inside the reservoir was uniform and not subjected to such great fluctuations as if exposed alternately to the hot sun and comparatively cool nights. The range of temperature during the construction period sometimes amounted to 80° Fahr. in 24 hours.

The expansion joints were left to the last, when a uniform temperature of about 70° inside permitted the filling of the joints, thus avoiding all trouble from expansion cracks.

The forms are shown in detail on Plate VII. They consisted of shutters stiffened with four trapezoidal trusses. The bottom posts of the trusses were fixed in holes formed in the foundation block; they were propped back from the embankment at the top, and secured to anchorages by iron rods.

Six sets of these forms were used to construct the whole wall. The concrete was placed in position through stove-pipe chutes, 20 cm. in diameter, in continuous layers, the workmen treading and spading it well as it was deposited. The forms were allowed to remain 4 or 5 days, and were then struck and removed to another section. The pedestals and capital forms were of lumber, and five of each were used to cast the total number required. In the column sections the outer steel forms used in the manufacture of the Estanzuela pipes were adapted for this purpose. The radial beam forms, shown on Plate VII, were arranged with internal wedge-shaped blocks to mould accurately the recess for the secondary beams. The bottom forms were left attached to the beams for 28 days, but the sides and ends were removed after 24 hours. Eight forms were sufficient for the whole 135 beams.

For the secondary beams, 29 forms were used for the 670 beams, the bottom lumber also being left until they were mature for handling.

By referring to the cross-section of the secondary beam, it will

be noticed that it is jug-shaped, shelves being left on either side for the support of the roof forms, which were placed after the secondary beams had been properly grouted to the radial ones. The lagging was laid diagonally, so that the short diameter was slightly greater than the distance between the beams. This greatly facilitated the removal of the lagging, as it was merely necessary to strike the wedge-shaped fillets beneath, and turn them clockwise, after tearing out the end lagging.

The writer believes that the adoption of forms of this type, rather than the ordinary kind, led to a saving of lumber of about 400 000 ft. b. m. During the erection and placing of the concrete, all the joining surfaces were carefully picked and cleaned, particular care being taken at the junction of the secondary with the radial beams, and the upper surfaces of all beams before laying the roof slab.

After the greater part of the roof was completed, the floor was laid in those sections where it was protected from the sun's rays. The concrete was placed in two 15-cm. thicknesses, and the work was carried on night and day, without any joints. The laying of the floor occupied 8 days, or an average of nearly 100 cu. m. daily.

Proportions of Concrete.—All the concrete work was brought to a smooth face by careful spading, no plastering being used throughout the reservoir, except in the superstructures. The work was kept well watered in every case for about 15 days. The whole of the concrete work in connection with the reservoir was completed in 5½ months. The concrete for the columns and foundations was a 1: 3: 5 mixture, the aggregate consisting of equal parts of 19-mm. (¾-in.) and 38-mm. (1½-in.) crushed stone. The remainder of the concrete, except that for the roof, was a 1: 2: 4 mixture, the aggregate also consisting of equal parts of 19- and 38-mm. stone. With the exception of a short length of the side-walls, the sand used was that manufactured by the Company. When the crushing plant was unable to produce all the sand required, the Hornos sand (see Table 3) was used in the side-walls in equal proportions with the crusher sand.

Reservoir Outlet and Entrance Tower.—The outlet, 61 cm. (24 in.) in diameter, leads from a well in the center of the reservoir and passes under the floor and embankment to an outside valve-pit, 89 m. from the center. This pipe was laid in a trench in a solid cutting before the construction of the embankment, and was encased in 1: 4: 8 concrete.

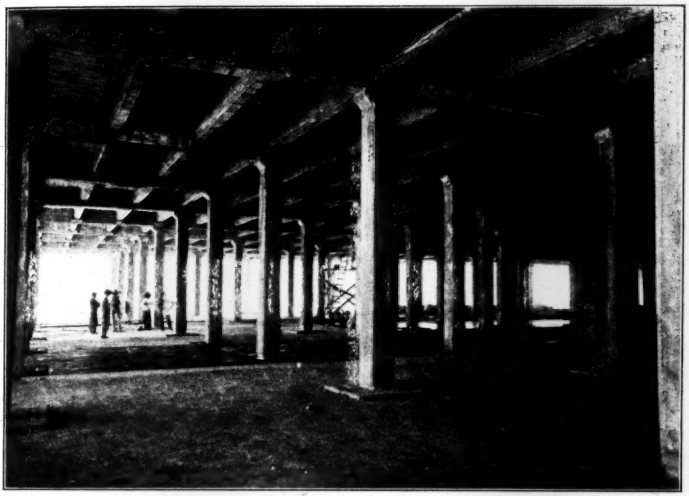


FIG. 1.—PREPARING FLOOR FOR CONCRETING, OBISPADO RESERVOIR.

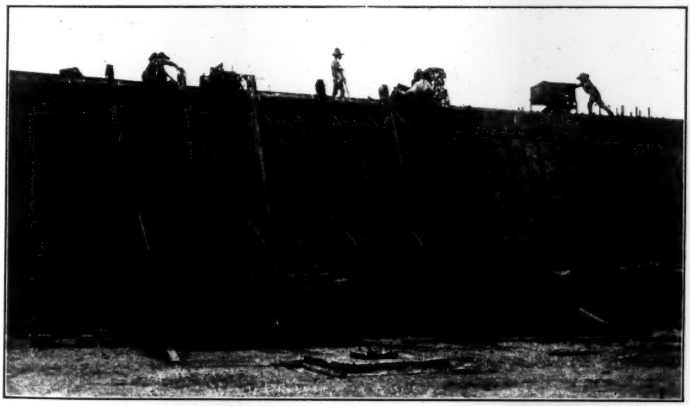


FIG. 2.—TRAVELING SIDE-WALL FORM, OBISPADO RESERVOIR.

Where it passes under the embankment a 1:2:4 concrete cut-off wall, 3.6 m. wide, 2.5 m. high, and 1 m. thick, was placed across it at right angles. The cast-iron pipe is curved upward in the central well, and has a bellmouth on which rests a movable circular copper screen.

Above the outlet well, and on the roof of the reservoir, there is a central tower, giving access to the interior by a steel stairway. This tower also serves as a main ventilating shaft, and in it are arranged the guide-screens and gearing for raising them for cleaning purposes. In addition to the ventilation provided in the tower, 20 circular openings, 30 cm. in diameter, are carried through the roof of the reservoir at the circumference and into the parapet walls.

Inlet Gate-House, etc.—The inlet gate-house is above the reservoir and about 54½ m. from its center. The conduit enters at 589.00 m. above datum, and the gate-house contains the valves for controlling the inlet pipe to the reservoir, the by-pass, overflow, scour-out pipe, and the copper screens. The inlet, which is 45.7 cm. (18 in.) in diameter, is of cast-iron flanged pipes, carried on iron hangers on the side-wall of the reservoir, and, at a point 90 cm. above the floor level, it is turned at right angles to the side-wall and carried on concrete piers to the center of the first row of columns. The end of the pipe is closed by a blank flange, and the water is deflected at right angles through two 30-cm. (12-in.) branches, for the purpose of setting up a slight circular motion as it enters the reservoir.

The valve-pit is clear of the embankment, and in it are brought together the main supply and by-pass pipes on which are placed two 61-cm. (24-in.) sluice-valves; and between them there is a 20-cm. (8-in.) scour-out pipe, for emptying the reservoir into an adjoining arroyo. The arrangement of the valves gives complete control over the contents of the reservoir.

Venturi Meter-House.—Fig. 11 shows the arrangement of the Venturi meter and its automatic register in a house over the main supply pipe. This house is designed to form a feature of the entrance gateway of the reservoir grounds, which cover an area of 12 hectares.

General.—The roof of the reservoir has been laid out as a garden, and the embankments are turfed. The intention is to develop the Company's land as a public park, as it commands fine views of the city and the surrounding mountains. An inspector's house has been built, and a private telephone line provides for communication with the Estanzuela intake and also with the general offices in the city.

San Geronimo Gravity Supply.

Provisional Supply.—It has already been stated that the Company began operations at San Geronimo in March, 1906, by sinking a well on the north bank of the Santa Catarina River at San Geronimo. At this point, a little later, a small steam pumping plant, sufficient to handle about 8 000 liters per min., was installed. The lowest depth to which this well was ultimately sunk in water-bearing strata, was 7 m., the normal level of the water during 1906 and 1907 never falling lower than 569 m. above datum. Tests made from time to time during 1907-08, showed that this well was capable of supplying nearly 10 000 000 liters (264 000 gal.) of water daily.

The excellent supply yielded by this well made it desirable to adopt it immediately as a provisional measure, pending the completion of the larger works forming the western source of supply. To utilize the well to its fullest extent, a reinforced concrete reservoir, of 3 000 000 liters capacity, was constructed on the south bank of the river, the top water level being 585 m. above datum, that is, at the same elevation as the proposed reservoir for the Estanzuela supply. The reservoir is 53.80 m. long, 21 m. wide, and has a water depth of 3.25 m. at the overflow level. It is excavated on a steep hill slope, and has an earth embankment on the lower side. The lining is of concrete, 20 cm. thick, and the roof is of reinforced concrete composed of flat arches springing from beams carried on 46 by 35-cm. reinforced columns. There are 68 of these columns, and they are 3 m. apart longitudinally and 5 m. apart transversely. The roof was not constructed until October and November, 1907, and prior to that time the necessity of covering the reservoir was amply demonstrated by the growth, during hot weather, of considerable quantities of green algæ, which had to be skimmed from the surface of the reservoir every few days.

The delivery pipe from the pumping plant was originally of riveted steel and was asphalted. It was 30 cm. in diameter, 2 mm. in thickness, with slip joints, and where it crossed the river it was encased in concrete. This pipe was afterward replaced by a cast-iron pipe of the same diameter. The supply pipe to the city was also of sheet steel, 30 cm. in diameter. For a part of its length it was laid in the high ground of the south bank of the river, which it crossed near the western limits of the city, and was then connected to a 30-cm. cast-iron pipe in the

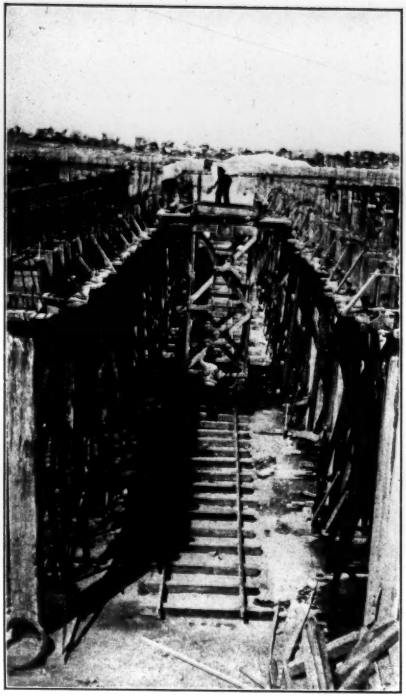


FIG. 1.—FILLING PRIMARY BEAMS FROM TRAVELING TOWER, OBISPADO RESERVOIR.

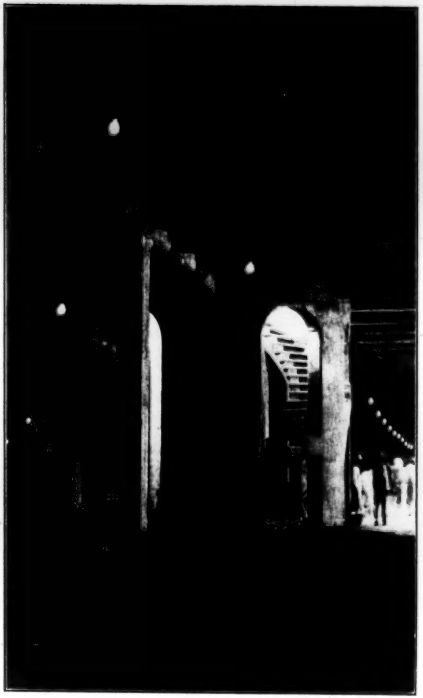
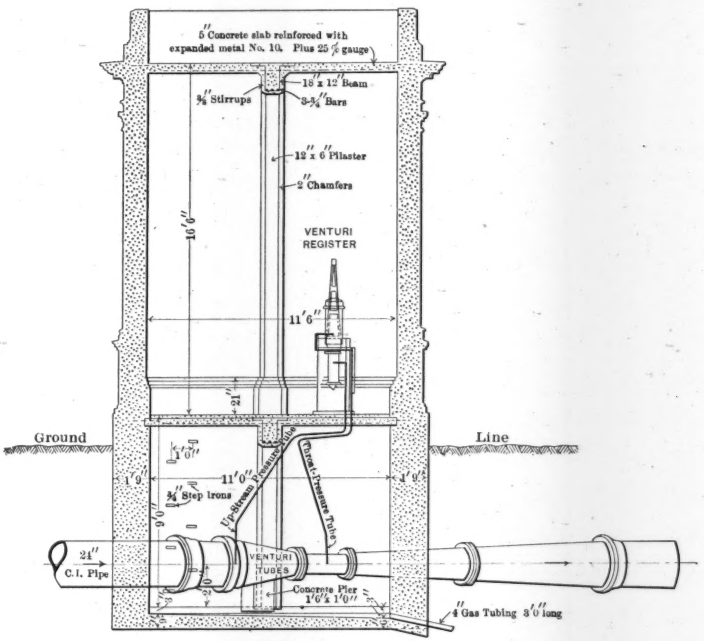
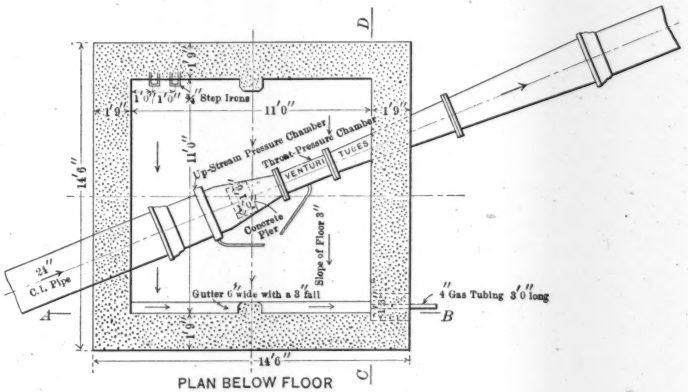


FIG. 2.—CENTRAL TOWER AND STAIRWAY, OBISPADO RESERVOIR.



SECTION A-B



PLAN BELOW FLOOR

FIG. 11.

distribution system. The total length of the pipe from the reservoir to the city distribution system was 2 850 m.

This provisional pipe continued in service from October, 1906, until August 27th, 1909, when the river portion was completely swept away, together with the provisional pump-house at San Geronimo, during the great flood in the Santa Catarina River. Fortunately, the permanent supply works were completed at the time, so that the destruction of this pipe line, which had already served its original purpose, had no effect on the supply of water to the city.

Infiltration Gallery.—The chief feature of the San Geronimo gravity supply is the infiltration gallery. By referring to the profile on Plate XI it will be seen that at this place there is a considererable area of what is undoubtedly water-bearing gravel. The main conditions were revealed by the borings previously carried across the valley, but the profile has been corrected to show the actual conditions as established at a subsequent date by shafts. Practically, the water-bearing strata are not limited merely to the sand and coarse gravels, as the clay formation lying above and below them is full of small gravel deposits containing considerable volumes of water. The main direction of the underflow is toward the east, and the hydraulic gradient, which was established from wells sunk farther west, was found to be approximately 1%, or practically the same as the average surface of the bed of the river above the line of the infiltration gallery.

The general scheme for tapping this underflow was to drive a main gallery at the 560-m. level on a grade of 0.05%, which was sufficiently high to take the supply by gravity to the western reservoir, having a top water level at 558.75 m. above datum. This elevation is sufficient to give an excellent pressure over about 60% of the city, and a fair pressure to reach the upper stories of the highest houses, if required, over the whole supply district. From this gallery it was proposed to sink shafts at frequent intervals, for a total distance of 300 m., carrying them below the gallery level, to tap any water-bearing gravels there might be in the clay formation underlying the gravels and sands. From the main gallery it was proposed to construct branch galleries up stream on a flat gradient, so as to obtain the advantage of an increased head due to the steep hydraulic gradient of the underflow water.

In investigations of this kind, it is of first importance to have a continuous record of the level of the water plane, and Fig. 12 has been

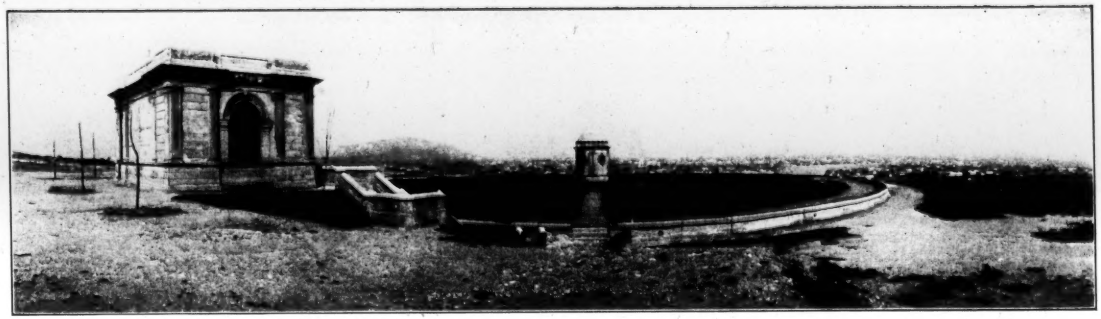


FIG. 1.—VIEW OF SOUTH RESERVOIR, LOOKING TOWARD THE CITY.

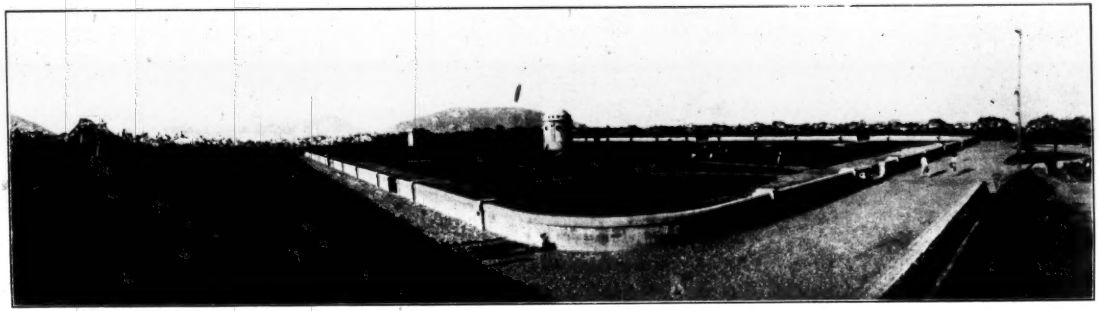


FIG. 2.—VIEW OF ROOF OF OBISPADO RESERVOIR, LOOKING NORTH.

plotted to show its variation at San Geronimo from the beginning of 1905 to March, 1910. From January, 1909, to March 31st, 1910, these levels are averages of daily readings taken in 9 shafts sunk along the proposed line of the infiltration gallery. In 1902 the water plane was standing at 570.18 m. above datum, but from that date until 1905 the writer has been unable to find any records. This diagram should be examined together with the rainfall diagram, Fig. 3, and it will be

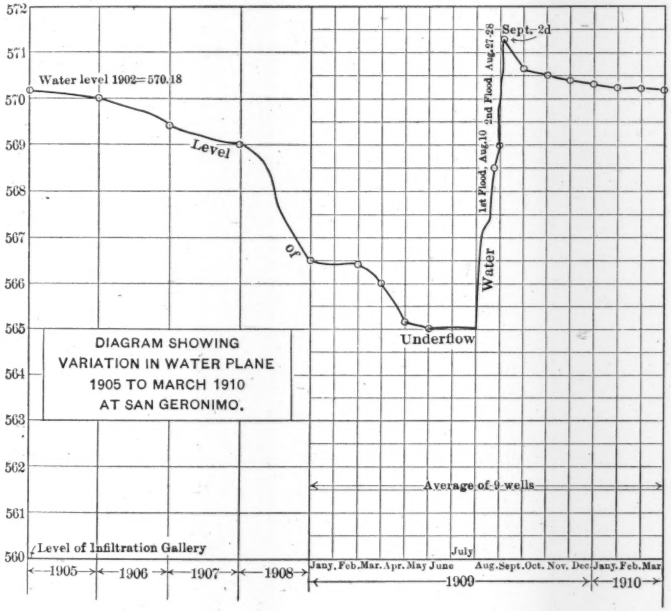


FIG. 12.

noticed that the fall in the water plane drops with the general scarcity of the rainfall during 1907-08, and until July, 1909. The year previous to July, 1909, is regarded by many competent local observers to have been the longest period of extreme drought in 30 years in Nuevo León, and the evidence which the writer has been able to gather regarding stream flow in the neighborhood of Monterrey supports this view. The total rainfall at Monterrey for the year prior to July 1st, 1909, amounted to 9.98 in., or 4.16 in. less than the lowest record for any

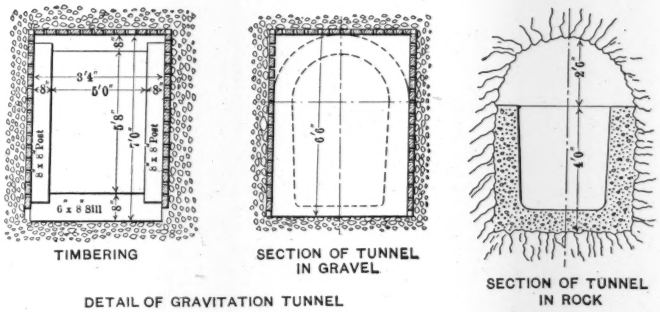
calender year since 1894, or, in other words, about 45% of the average annual rainfall.

The lowest point to which the water plane dropped was during June and July, 1909, when the levels stood slightly above 565.00 m., or 5 m. above the level of the floor of the infiltration gallery. During this period pumping tests were made in the various wells, and from these it was quite clear that the infiltration gallery, if carried far enough to meet them all, would yield a supply of from 25 000 000 to 40 000 000 liters daily. During the great rainfall of August, 1909, the water levels rose very rapidly; the heavy precipitation between August 9th and 10th caused the level to rise to 568.00 m. in about 4 days, and 6 days after the great flood of August 27th, the water level, which had continued rising gradually, reached 571.40 m., and then fell gradually until at the end of March, 1910, it was practically the same as it had been from 1902 to 1905.

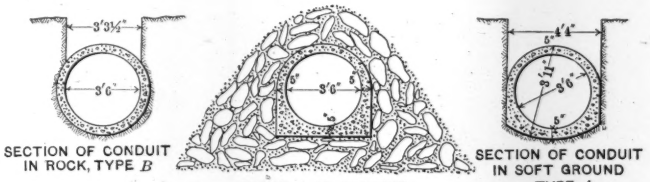
It should be noticed that the readings were taken in the shafts on the high ground to the west of the present river bed, and were independent of any flow there might be in the river. During times of ordinary floods in the river, it was very noticeable that, notwithstanding the fact that the river water might be turbid to an extreme degree, the well even in immediate proximity to the river bed did not show the least sign of discoloration.

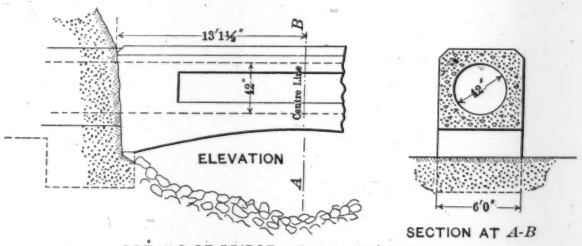
Design of Works.—Plate XII shows the general design of the gravity scheme, which consists of a main tunnel 550 m. long and a concrete aqueduct, 1.06 m. (42 in.) in internal diameter and 2 311 m. in length, discharging into a low-service distributing reservoir at the extreme western limits of the city. The tunnel and aqueduct were laid on a gradient of 0.05%, and the latter was designed to discharge 55 000 000 liters per day (22.8 cu. ft. per sec.) if flowing to its full capacity.

Gravitation Tunnel.—This tunnel, shown on Plate XII and Fig. 13, was completed prior to driving the infiltration gallery into the water-bearing gravel, so that the water encountered in the gallery could be easily drained off by gravity, thus avoiding a heavy outlay for pumping. The tunnel passes through various strata, the principal ones being calcareous shale, conglomerate, and gravels. The tunneling operations were carried on from 5 shafts, No. 1 being 23 m. deep, and the others varying from 20 to 10 m. The shafts in loose ground were

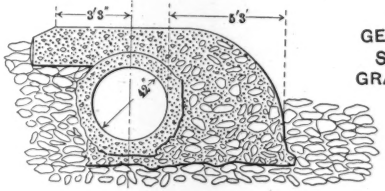


DETAIL OF GRAVITATION TUNNEL





DETAILS OF BRIDGE AT STA. 19+63.0



DETAIL OF SPECIAL SECTION ACROSS RIVER

FIG. 13.

timbered in the usual way, having clear inside dimensions of 2 m. Shaft No. 1, which was entirely in shale, was taken out approximately to 3.35 m. in diameter, so as to permit it to be lined with concrete having a finished internal diameter of 2.43 m.

Fig. 13 shows the details of the tunnel, which was lined with concrete, the bottom and sides being approximately 23 cm. (9 in.) thick. The interior dimension is 0.91 m. at the invert level and 1.016 m. at a height of 1.22 m., the corners between the side-walls and the floor being slightly curved. The arch is formed of two rings of brickwork in cement mortar, this thickness being increased in some lengths to three rings. Where the rock was in good condition, and not likely to disintegrate easily, the arch, for a distance of 90 m., was left unlined. Of the total distance of 550 m., careful timbering was required for 300 m. In lining the timbered portion of the tunnel with concrete, all the timber was removed, except in loose ground, where the laggings were left in position.

While the tunnel was being driven, a start was made to drive the north end of the infiltration gallery, which was in rock for a distance of 44 m. Water appeared at about 35 m., and then the work was temporarily suspended until the gravitation tunnel was completed and a length of the aqueduct had been constructed far enough down stream on the north bank of the river to permit of draining direct to the river. This point was reached at 1 170 m. from Shaft No. 1, and there a temporary overflow chamber was constructed.

When the tunnel was completed, the two intermediate shafts were filled up, the remaining three being retained permanently. Shafts Nos. 2 and 3 were lined with concrete, 76 cm. (30 in.) in internal diameter, and 23 cm. thick. They were domed at the top to form circular openings to receive cast-iron covers. Progress on this tunnel was slow, taking from December, 1907, to November, 1908, to complete, owing chiefly to difficulties with an incompetent contractor. The contract was subsequently transferred to Mr. John Phillips, of Mexico City (who was also the contractor for the aqueduct), who completed it satisfactorily.

Continuation of the Infiltration Gallery.—When the aqueduct (to be referred to again) was completed as far as 1 170 m. from Shaft No. 1, the driving of the infiltration gallery, which was 2 m. high and 1½ m. wide, was continued until gravel was encountered in the roof, at 44 m.

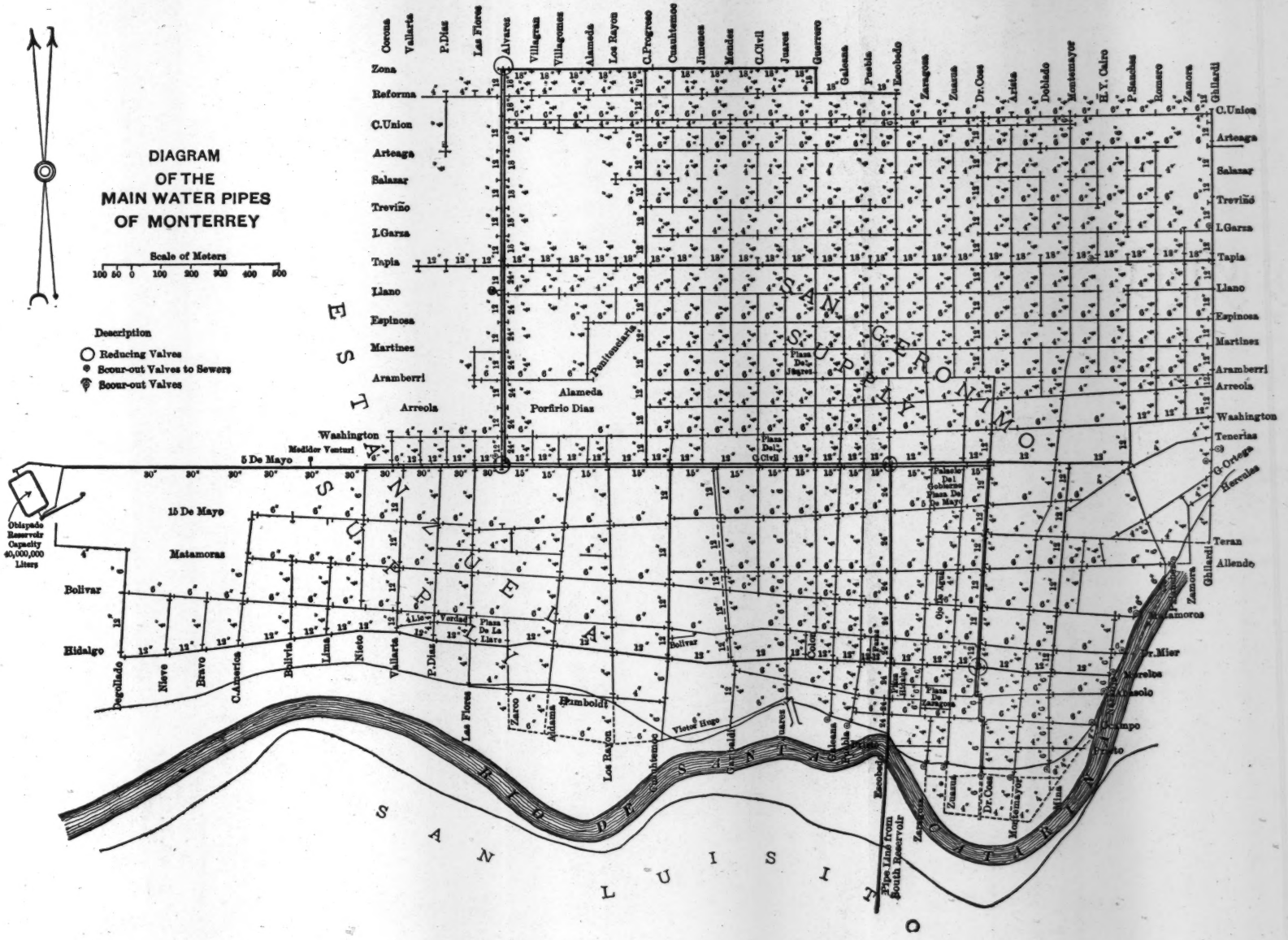


DIAGRAM
OF THE
MAIN WATER PIPES
OF MONTERREY
Scale of Meters
100 50 0 100 200 300 400 500
Description
Reducing Valves
Scour-out Valves to Sewers
Scour-out Valves
Obispado Reservoir Capacity 40,000,000 Liters
ESTANZUELA SUPPLY
SAN GERONIMO SUPPLY
RIO DE SANTA CATARINA
SAN LUISITO
Zona
Reforma
C.Union
Arteaga
Salazar
Treviño
I.Garza
Tapia
Llano
Espinosa
Martinez
Aramberri
Arreola
Washington
Medidor Venturi
5 De Mayo
15 De Mayo
Matamoras
Bolivar
Hidalgo
Degollado
Nieve
Bravo
C.America
Bolivia
Lima
Nieto
Vallarta
P.Diaz
Las Flores
Zarco
Aldama
Humboldt
Los Rayon
Guauhtemoc
Garibaldi
Juarez
Galeana
Puebla
Escobedo
Zaragoza
Zuazua
Dr.Coss
Montemayor
Mina
Ocampo
Prieto
Morelos
Abasolo
Dr.Mier
Matamoros
Allende
Teran
G.Ortega
Hercules
Tenerias
Washington
Arreola
Aramberri
Martinez
Espinosa
Llano
Tapia
I.Garza
Treviño
Salazar
Arteaga
C.Union
Ghilardi
Zamora
Romero
P.Sanchez
H.Y. Cairo
Dobladо
Arista
Zuazua
Dr.Coss
Montemayor
Zaragoza
Escobedo
Puebla
Galeana
Guerrero
Juarez
C.Civil
Mendez
Jimenez
Cuauhtemoc
C.Progreso
Los Rayon
Alameda
Villagomez
Villagran
Alvarez
Las Flores
P.Diaz
Vallarta
Corona
Alameda
Porfirio Diaz
Penitenciaria
Plaza Del Juarez
Plaza Del C.Civil
Palacio Del Gobierno Plaza De 5 De Mayo
Plaza De La Llave
Plaza De Zaragoza
Plaza Hidalgo
Ojo De Agua
Victor Hugo
Verdad
Bolivar
Colon
Pipe Line from South Reservoir

from the shaft. At this point the rock dipped at an angle of 45°, and the gravels contained quantities of large boulders mixed with fine sand; immediately after encountering the gravel, a flow of about 90 liters per sec. was met, evidently coming through from a pot-hole in the shale. This quantity diminished in about 10 days to about one-fourth, but gradually increased again as the driving proceeded. The operations of driving the tunnel from 44 m. forward were begun in the dry season, in February, 1909, and the gravel was encountered for a distance of 24 m., or up to 68 m. from the shaft. The center of this gravel bed was about 30 m. south of the old river channel, which had been continuously dry at the surface for several years. Up to 68 m. the work was very difficult, owing to the upper part being of loose gravel and the lower in very contorted shale. The timbering of the tunnel in the full gravel section consisted of heavy square settings, 1 m. apart. At 68 m. the clay and gravel formation was met, and the rate of progress then was about 4 or 5 m. a week. A short branch gallery was also driven about 7 m. up stream near Shaft No. 2. The total distance the infiltration gallery was carried from Shaft No. 1, was 100 m., when the floods of August, 1909, caused its suspension.

During the progress of the gallery, attempts were made to sink a 3½ by 2-m. shaft at a point along the line of the infiltration gallery, about 130 m. from Shaft No. 1, but water in such abundance was encountered that it was practically impossible to sink it in the ordinary way more than about 6 m. deep, the quantity of water to be dealt with amounting to about 20 000 000 liters daily. Seven shafts were then sunk in the high ground to the north of the river, five of these being on the line of the gallery and two 30 m. westward. They were sunk during the dry season prior to July, 1909. These were ordinary timbered shafts, 2 m. square between the walings, and were carried to the depths shown on Plate XI. In Shafts Nos. 5, 6, and 7 the water was flowing with considerable velocity, while Shaft No. 9 seemed to have penetrated a different water plane and one which was probably independent of that showing in any of the other shafts, in which the water was practically at a uniform level. The evidence obtained showed that if the gallery could be carried to Shafts Nos. 6 or 7 a great abundance of water would be intercepted. Owing to the difficulties of sinking ordinary shafts in the wide river channel, circular shafts were put down. These were 1.37 m. in internal diameter and 23 cm.

thick, and were of concrete reinforced with No. 10 vertical rods, 19 mm. in diameter, tied together with No. 6 wire. These shafts were provided with steel cutting edges.

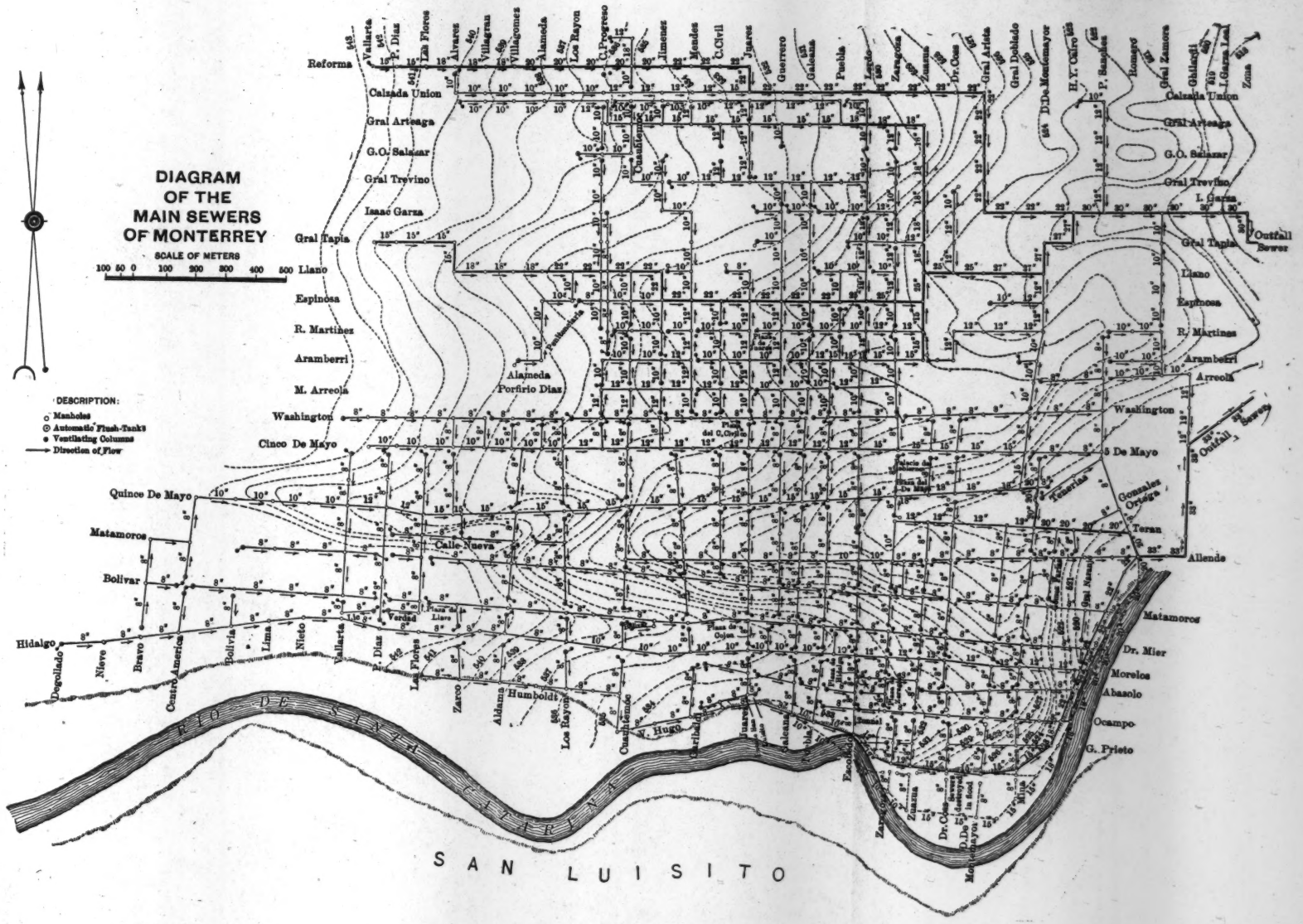
Shaft No. 2 was sunk to a depth of 1 m. below the infiltration gallery level, No. 3 within 2 m., and No. 4 within 4 m., before August, 1909. The shafts were sunk by digging them out and loading them at the top, the top of the shafts being kept generally 3 m. out of the ground. Shaft No. 3 encountered great volumes of water, and, in order to enable sinking operations to proceed, a pumping shaft, 2¼ m. square, was sunk a little west of it to draw off the water. Notwithstanding the fact that the prolonged period of drought had lowered the general water plane in all the shafts to 565.00 m. above datum, the difficulties of handling the water even at that level were considerable. At the beginning of August the work was progressing very satisfactorily, but the extraordinary rainfall of that month caused the work to be shut down temporarily.

Effect of the Floods in the Santa Catarina River.—The area of the water-shed of the Santa Catarina River above Monterrey is about 1 410 sq. km. (544 sq. miles), and its area at San Geronimo, owing to its configuration, is practically the same. Its general character has already been referred to. On the night of August 10th and early on the morning of August 11th, a big flood came down the river, flowing at its maximum about 1 130 cu. m. (40 000 cu. ft.) per sec., due to the heavy rainfall (Fig. 4). This flood carried away all the temporary staging around the shafts, seriously wrecking the temporary pumping station, as well as destroying the 30-cm. cast-iron pipe, notwithstanding the fact that it had been encased in a block of concrete 3 m. wide and 1½ m. thick right across the river; but no damage was done to the infiltration gallery or to the shafts in the river channel. The effect of the flood on this pipe is shown by Fig. 2, Plate XXXI.

Following this flood, which had caused the loss of 14 lives in the city, 3 miles below San Geronimo, there was practically no rain for 13 days. Then, on August 25th the second heavy precipitation began and continued until August 29th, the details being shown on Fig. 4.

This precipitation, therefore, fell on a water-shed which was completely saturated, as it had already absorbed a large proportion of the 13.38 in. of rain which fell during August 10th and 11th; and at every point along the river, prior to August 25th, springs were issuing forth,

PLATE XX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXII, No. 1193.
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



and there had been very little evaporation during the intervening dry spell.

The writer has calculated that at Monterrey this flood reached the enormous quantity of 6 650 cu. m. (235 000 cu. ft.) per sec., a rate equal to 432 cu. ft. per sec. per sq. mile of water-shed.* The effect of this flood was to demolish completely about 1 200 "sillar" houses (without taking into consideration the numerous wooden houses) at Monterrey, and to cause a fearful loss of life, variously estimated between 3 000 and 5 000 persons; the lower figure the writer believes is approximately correct. At San Geronimo the original pumping station was carried away entirely, leaving practically no trace whatever.

Shaft No. 2 was apparently destroyed, while No. 3 was turned at an angle of about 50° down stream and filled up completely with sand. The infiltration gallery, near Shaft No. 2, was completely blocked with fine sand and gravel, and access could only be obtained as far as 54 m. The profile, Plate XI, shows the change which had taken place in the river bed. The original course of the stream was changed to the north bank, 50 m. distant, the effect of the scouring action of the flood being to lower the general level at this point about 3.65 m., while the southern portion of the channel was slightly raised. At present (April, 1910), the end of the driven portion of the infiltration gallery is about 35 m. from the center of the stream, which is still carrying about 2 270 liters (80 cu. ft.) per sec.

Immediately after the flood the flow in the gallery was 450 liters (16 cu. ft.) per sec., and this quantity has remained constant since that time. The probable effect of the flood was to disturb the whole subsurface above the infiltration gallery and put it in motion, completely cleaning the gravels of their surrounding clay, which would account for the large infiltration of water in so limited a distance. The water has always been limpid and pure, but its hardness remains the same as it was prior to the flood.

With the copious supply of water from this source, due of course to abnormal conditions and not likely to be permanent, the operations of tunneling have been suspended temporarily; but it is proposed to

* The writer, in a brief article contributed to *Engineering News* soon after the flood (September 23d, 1909), gave this figure as 271 500, or approximately equal to a run-off of 500 cu. ft. per sec. per sq. mile; but, from a later and more complete study of the conditions for many miles above Monterrey, he believes the above quantity to be approximately correct.

continue the driving of the gallery, from a new shaft west of No. 3. The water encountered will be drained off by pumping until the main water-bearing gravels, in the neighborhood of Shaft No. 5, are reached. It is also proposed to reconstruct the 30-cm. high-level pipe line, from San Geronimo along the high road on the north bank of the river, so that by pumping water can be delivered to the city system from Shafts Nos. 5, 6, and 7, in the event of a shortness of supply from the Estanzuela River.

Shaft No. 1.—Shaft No. 1 is designed to connect the infiltration gallery with the gravitation tunnel. This shaft has an inner diameter of 2.43 m. (8 ft.) and is fitted with a special gate-valve. In the bottom of the door of this valve there is a smaller valve, 30 cm. in diameter, so that, when the infiltration gallery is closed for cleaning out the sump, the smaller door, which is operated through the same spindle by a bevel-geared head-stock at the top of the shaft, can be opened first. Space is also left for screens if these should be found necessary. Access to this shaft is gained by a reinforced concrete stairway in nine stages. The superstructure is to be supported on reinforced concrete column foundations carried to the firm rock, owing to the loose condition of the strata at the top of the shaft.

Aqueduct.—The construction of the concrete conduit was begun in April, 1908. Fig. 13 shows the general types. Type *A* was adopted in gravel and conglomerate formation, and Type *B* where the excavation was in "sillar," the soft nature of this rock permitting it to be excavated exactly to the required external diameter of the concrete lining.

The concrete which was without steel reinforcement was a $1:2\frac{1}{2}:3\frac{1}{2}$ mixture, the sand being from the crusher and the aggregate from the river bed, screened to pass a 25-mm. mesh. Where the conduit crossed the river obliquely, immediately below the gravitation tunnel, it was strengthened with mass boulder concrete of Type *C*. During the great flood this heavy section withstood its effects without damage of any kind, but beyond this point, where the conduit had been laid in compact cemented gravels, the scouring action of the flood on the north bank lowered the level of the gravels from 2 to 3 m.; the only damage, however, was the scouring away of the gravels at the south side of the conduit. To prevent such an occurrence in the future, the conduit at that point was strengthened with additional concrete for a distance of

FIG. 1.—VIEW OF ARCH, OUTFALL SEWER.

FIG. 2.—VENTILATING COLUMN AND MAN-HOLE, OUTFALL SEWER.

195 m., as shown on Fig. 13. The extra concrete, amounting to 733 cu. m., was a 1: 3: 5 mixture, in which was embedded 20% of heavy boulders. The top of this special length now forms a weir for the present river flow. Where the conduit enters the bluff on the north side of the river, at 1 200 m., there is an overflow chamber which has a sluice-gate 76 cm. wide, arranged so that the conduit can overflow at the present time when running 76 cm. deep. To deflect the flow in the conduit, a wrought-iron plate, provided with a balance weight, is dropped into a groove on the lower side. The outlet is a 61-cm. concrete tube, having its invert above ordinary flood level, and arranged to be closed by a gate.

At 1 963 m. the conduit is carried over an arroyo on a segmental arch of 8 m. clear span, as shown on Fig. 13. There are 5 ventilating columns and 5 manholes on the aqueduct.

The aqueduct terminates in the Obispado distributing reservoir valve-house, at a level of 558.50 m. The work in connection with this aqueduct was completed by December, 1908.

Distributing Reservoir at Obispado.

The main distributing reservoir for the San Geronimo gravity supply is immediately below the historic Obispado (Bishop's Palace), at the western limits of the city. The general arrangement and lay-out is shown on Plate XIII.

Valve-House.—The invert of the conduit from San Geronimo, where it enters the valve-house, is 558.50 m. above datum. The valve-house, which is built in the center of the reservoir, is shown on Fig. 2, Plate XVIII. One of its special features is the provision of the main overflow at this point instead of within the reservoir proper. The inlet, main supply tunnel, independent by-pass overflow, scour-out pipes, gate-valves, and screens, are all controlled within the valve-house.

Reservoir.—The reservoir is rectangular, 126 by 81 m. (413.28 by 265.68 ft.) at the top, and has a water depth of 4 m. (13.1 ft.). In the design it was necessary to limit it to the lowest economical depth, so as to increase the static pressure over the low-pressure district as much as possible.

Excavation and Embankment.—The excavation, except for a depth of about 1 m. which was in black soil, was chiefly in a disintegrated

"sillar" stratum of a heavy clayey nature, the greater part of which could be handled conveniently with plows and scrapers; the actual foundation on the eastern half required blasting for the final depths.

The total excavation amounted to 56 479 cu. m., of which 7 255 cu. m. were placed in the embankment, the remainder being deposited in the immediate neighborhood of the reservoir. The final trimming of the banks, which were left 30 cm. full, was not undertaken until the lining was begun. The work was done under contract with Mr. J. S. Nickerson, of Monterrey. The excavation had only one classification, and the contract prices were 0.50 peso per cu. m. for material carried to spoil banks, and 1.00 peso for material placed in the embankment. The excavation was begun in December, 1907, and completed in April, 1908. The work was then left standing until the end of 1908 to allow the banks to consolidate thoroughly prior to lining, which was begun on January 4th, 1909.

Concrete Lining and Roof.—Plate XIII shows the general plan and sections, the main feature being the simple division of the reservoir into 24 rows of columns longitudinally and 15 rows transversely, making a total of 360 columns, less the four left out at the central tower. All the columns are 5 m. apart both ways. The roof was designed for a live load of 100 lb. and a dead load of 150 lb., the same as at the South Reservoir. With the exception of the floor, all the concrete work was reinforced with twisted steel lug bars. The foundation load on the columns for the eastern half of the reservoir is 0.9 ton per sq. ft.; that on the columns for the western half, where the foundation is of very hard sillar and conglomerate, is 1.95 tons per sq. ft.

Underdrainage of the Floor.—To provide for proper drainage in case of seepage, the floor was underdrained with rubble drains, 30 cm. wide and 23 cm. deep, filled with large round gravel carted from the bed of the Santa Catarina River. The total length of these underdrains is 1 160 m. In order to facilitate the detection of any seepage, they were conducted to a permanent inspection pit outside of the reservoir.

Main Distributing Conduit.—The main distributing conduit is laid along the inside of the reservoir, at the inlet end, and carried on elliptical arches of 2 m. span to a height of 71 cm. above the finished floor level. This conduit is 76 cm. high and 45.7 cm. wide, and it branches in two directions from the inlet tunnel to each side of the

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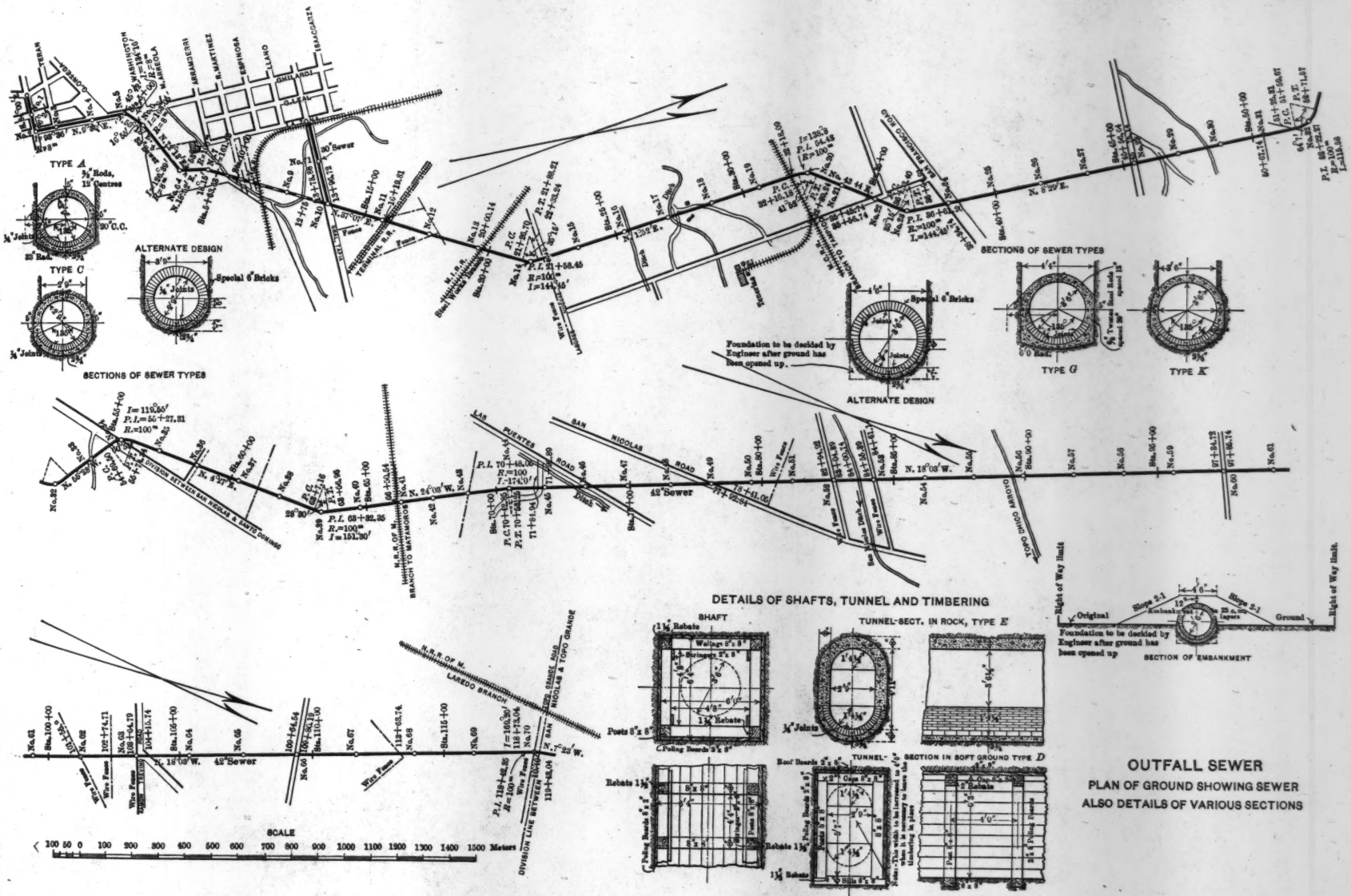

OUTFALL SEWER

PLAN OF GROUND SHOWING SEWER
ALSO DETAILS OF VARIOUS SECTIONS

reservoir, its total length being 69 m. In order to prevent any stagnation and to give a continuous circulation, the water is delivered at eight points, in the length of the distributing pipe, through square openings with semicircular tops, the areas of the openings increasing toward the ends. These inlets are placed so that the current will not strike the roof columns.

Outlet Tunnel and Valve-House.—The outlet tunnel is at the north end of the reservoir, and was excavated in hard sillar rock. The tunnel is lined with concrete 30 cm. thick, the finished internal dimensions being 1.52 by 0.91 m. The length of the tunnel is 22.5 m. to the point where it enters the outlet-house. This house is divided by a wall 45 cm. thick, which supports a 76-cm. (30-in.) penstock-valve. The supply pipe to the city leaves this chamber in the west wall, and is also fitted with a 76-cm. penstock-valve. The supply pipe has a copper screen of the same design and dimensions as those in the inlet-house. A 30-cm. (12-in.) scour-out pipe in this chamber provides for draining the contents of the reservoir to a neighboring irrigation ditch, when necessary.

The superstructure of the valve-house is of concrete, and at the floor level there are bevel-geared head-stocks to raise the valves, etc.

By-Pass and Supply Pipes.—The by-pass and supply pipes are carried below the reservoir embankment to join the main 76-cm. (30-in.) cast-iron distributing pipe to the city. For this short distance they were constructed of concrete, 76 cm. in internal diameter, 10 cm. (4 in.) thick, reinforced with 6½-mm. square steel longitudinal rods, 30 cm. from center to center in the circumference, and hooped with 6½-mm. square steel rods spaced 30 cm. apart. The concrete forming these pipes was a 1: 1½: 2½ mixture.

Parapet Walls.—The parapet walls have 12 piers at each side and 8 at each end. In these piers there are ventilating openings branching at the top to each side of the parapet, with outlets provided with cast-iron screens. This arrangement gives 4 sq. m. of ventilating space (exclusive of that provided in the central tower), equally distributed at 40 points around the walls of the reservoir.

General Construction Scheme.—The concrete mixing plant, which consisted of two No. 1 Smith mixers, was arranged in connection with the bins and hoppers for the rock and sand on the high ground to the west, and from there the material was conveyed on a framed timber

gangway carried right across the center of the reservoir, as shown by Fig. 1, Plate XVII. From this central platform the concrete for the columns was filled from stages placed on the top of traveling towers, 5 m. high, which were run between two rows of columns on standard-gauge rails laid on the floor of the reservoir. By this arrangement 24 columns could be filled from each length of track. A main narrow track was also laid right around the reservoir, with the necessary turn-outs.

The forms for the columns, primary and secondary beams, are shown on Plate XIV. The side forms for the primary beams were struck in 24 hours, so as to economize lumber; but the bottom lumber was left in position for 28 days. To avoid much unnecessary timber, the secondary beam forms were supported at the ends on reinforced concrete corbels cast on the primary beams.

For placing the side-walls, a special traveling form was used, the details of which are shown clearly on Plate XIV. At the end of each form an expansion joint of 25 cm. was left to be filled after the roof was placed in position. The concrete was delivered to the wall through stove-pipe chutes, and carefully spaded by workmen in the limited space between the forms and the embankment. The wall form was removed after 36 hours, by loosening the jacks and pulling forward the hooked tie-rods. This form is also shown on Fig. 2, Plate XVI.

The concreting of the roof slab was carried on continuously, and, when partly completed, the floor was laid in the shade. The bottom layer of the floor, 13 cm. thick, was laid in continuous panels between the columns, and brought to a fairly smooth surface. On this surface, after keeping it wet for 10 days and then allowing it to dry thoroughly, a layer of asphaltum, supplied by the American Asphaltum and Rubber Company, of Chicago, was placed. The work was done by ordinary Mexican laborers after they had received a few days' instruction from one of the Asphaltum Company's superintendents. The surface of the lower layer was kept perfectly clean, and then received one coat of "Pioneer" paint. The asphaltum, heated in a boiler inside the reservoir to a temperature of approximately 425° Fahr., was then poured over the floor from buckets, in a layer approximately 4 mm. thick. Where the floor joined the column pedestals, and at each new panel section, a double thickness was used. The labor cost of water-proofing, including superintendence, etc., amounted to

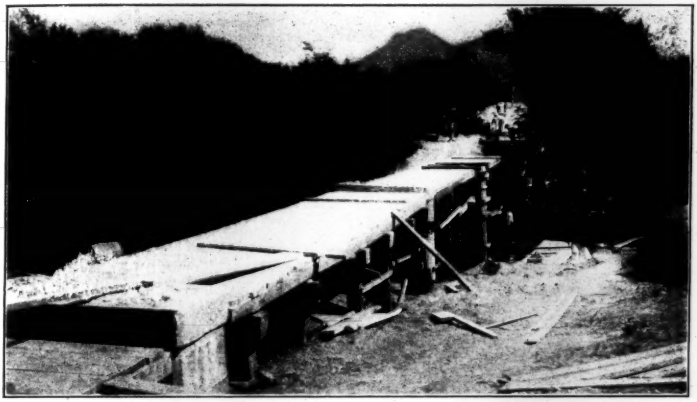

FIG. 1.—FORMS FOR MAIN GIRDERS, ESTANSCIA BRIDGE, OUTFALL SEWER.

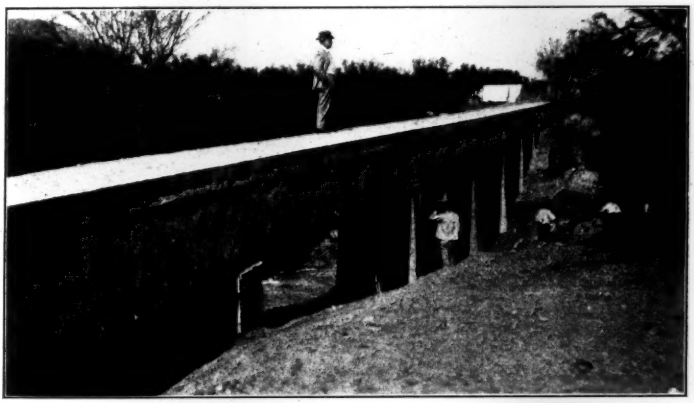

FIG. 2.—VIEW OF ESTANSCIA BRIDGE, COMPLETED.

3.3 cents (Mexican) per sq. m. for painting with "Pioneer" paint, and 5.4 cents for the asphaltum coating, or a total labor cost of 8.7 cents per sq. m. for the complete water-proofing. This cost is based on a rate of 8.00 pesos per day for a foreman, and 1.00 peso for each laborer. It required 50 U. S. gal. of the paint to cover 265.2 sq. m., and an average of about 6 lb. of asphaltum for 1 sq. m.

The upper concrete layer of the floor, 10 cm. thick, was placed so as to break joint with the lower, and was brought to a smooth surface with wooden floats sheathed with steel and reaching across the panels. In this way a perfectly smooth surface was obtained without any plastering.

The concrete for the beams, columns, side-walls, and floor, was a 1: 2½: 4 mixture, crushed sand and stone being used throughout. In the roof slab the mixture was 1: 2: 3.

The whole of the concrete work of the reservoir was completed in 6 months, by the Company's own administration, and the reservoir was first put into service a few days after the great flood of August 27th, when the Estanzuela supply main, crossing the Santa Catarina River, was partly destroyed. Since that time frequent examinations of the inspection pit, which is connected by a pipe to the rubble drains under the floor, have never revealed the slightest leakage.

Lay-Out of the Reservoir Roof and Grounds.—The Company owns about 11½ hectares of land, which includes that occupied by the reservoir and its surroundings, and as this property is in an attractive situation, commanding fine views of the Sierra Madre Mountains, the whole of the works have been given a pleasing architectural character, and the grounds laid out to form a public park for the citizens of Monterrey.

The general plan of the scheme is shown by Fig. 14 and Fig. 2, Plate XVIII. The roof, which has an area of 1 hectare, has been laid out with walks and grass plots, and the surrounding embankments have been converted into driveways. Above the reservoir a small plazuela of ½ hectare has been laid out with a space above it for a band-stand. The whole of the ground has been encircled with carriage drives, on which it is the intention to plant shade trees. The lay-out of this land also embraced the scheme for protecting the reservoir by draining the surface-water away to the irrigation ditches.

COMPARISON OF SOUTH AND OBISPADO RESERVOIRS.

The two reservoirs are practically of the same capacity, the only difference being the level of the overflows in their relationship to the roof, which gives the Obispado Reservoir a slightly greater

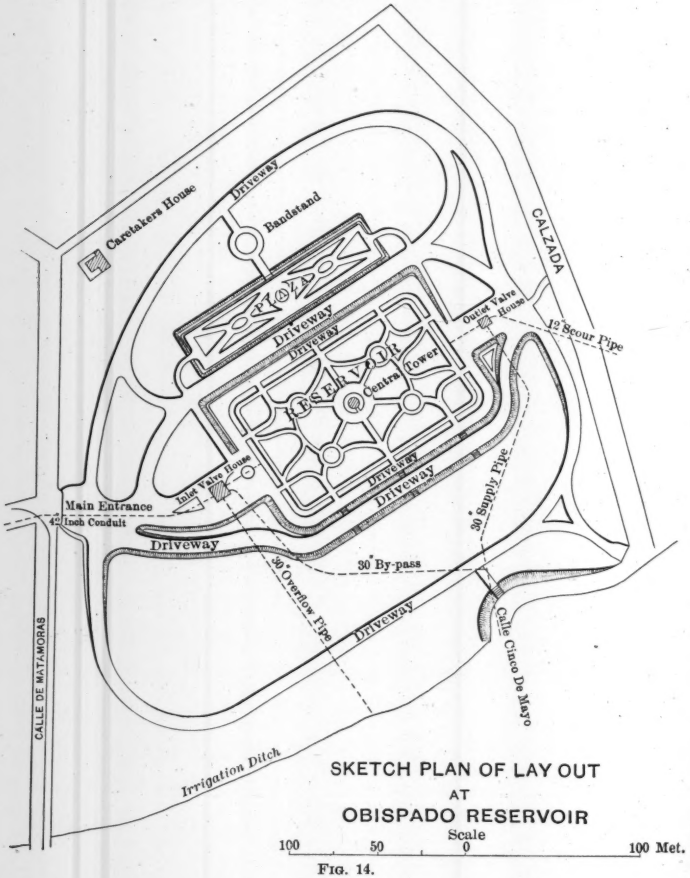

FIG. 14.

capacity. Some comparative figures may be of interest, owing to the differences in type and construction. Table 7 gives the comparative quantities of material in each reservoir proper, that is to say, exclusive of the valve-houses, lay-out of grounds, etc.

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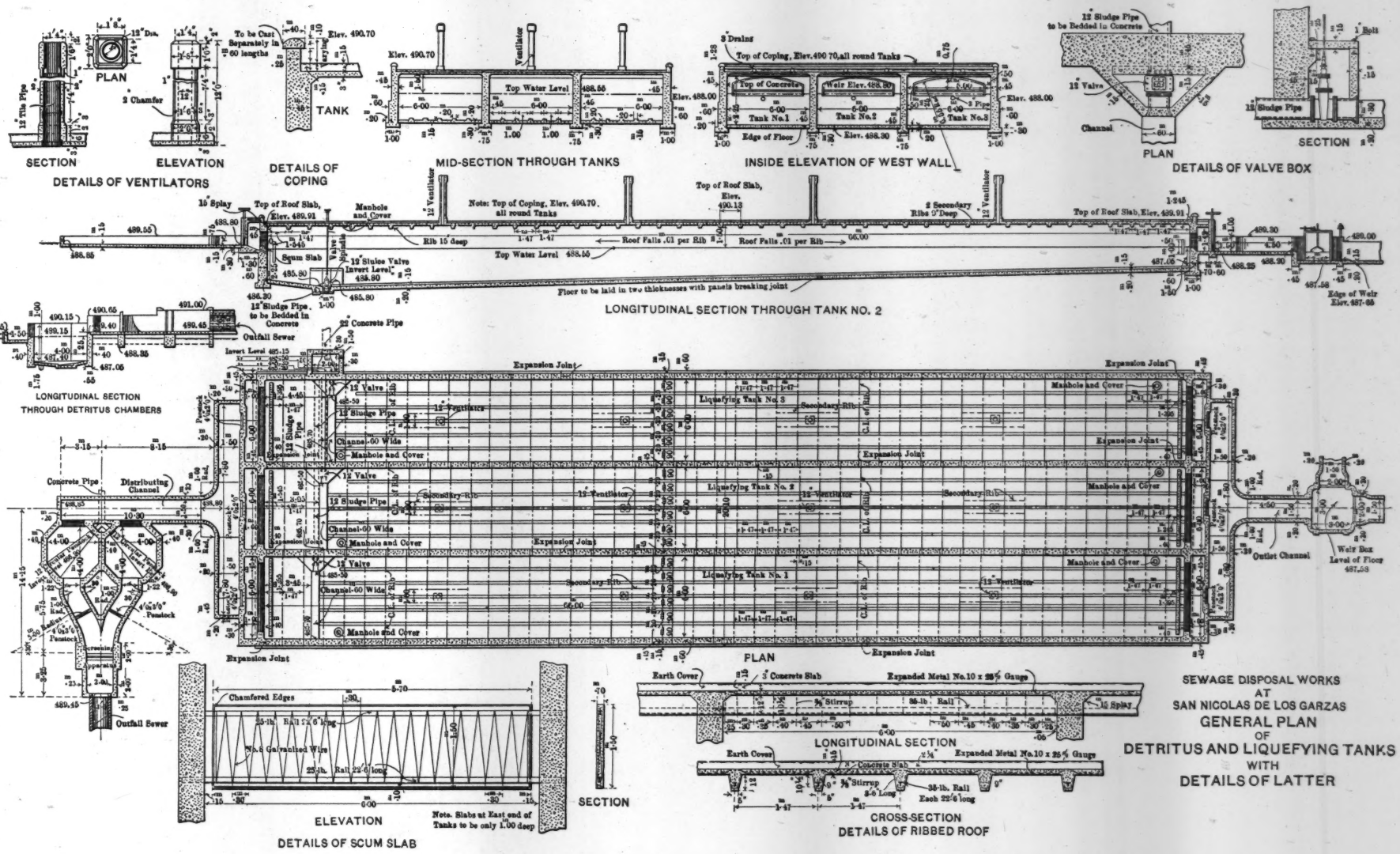

SEWAGE DISPOSAL WORKS AT SAN NICOLAS DE LOS GARZAS

GENERAL PLAN OF DETRITUS AND LIQUEFYING TANKS WITH DETAILS OF LATTER

TABLE 7.—COMPARISON OF MATERIALS IN SOUTH AND OBISPADO RESERVOIRS.

	South Reservoir.		Obispado Reservoir.	
	No.	Quantities, in cubic meters.	No.	Quantities, in cubic meters.
Earthwork:				
Total excavation	.....	34 000	.....	56 479
Placed in embankment	.....	31 500	.....	7 255
Placed in spoil banks	.....	2 500	.....	49 224
Concrete:				
Columns (including foundations)	135	1 240	356	543
Primary beams	135	440	374	462
Secondary beams	670	515	1 252	576
Side-walls	.....	1 255	.....	710
	Square meters.		Square meters.	
Roof slab	5 140	520	10 206	1 020
Floor	4 070	780	9 200	2 120
Parapet walls	.....	90	.....	165
Total concrete	.....	4 840	.....	5 596
		Pounds.		Pounds.
Reinforcing steel bars	.....	387 000	.....	380 000
		Square meters.		Square meters.
Expanded metal in roofs, slabs, etc.	.....	5 691	.....	10 490

The total cost of these reservoirs, including valve-houses, by-passes, and the length of supply pipe where the by-pass joins, and including all engineering expenses, etc., but exclusive of the cost of lands, planting, fencing, and special work in connection with the formation of parks, was as follows:

South Reservoir: 394 000 pesos, or 10 368 pesos* per million liters.

Obispado Reservoir: 375 000 pesos, or 9 375 pesos* per million liters.

These rates may be regarded as reasonable when taking into consideration the special difficulties of construction in Mexico, and the high cost of all imported material, on which heavy duties are levied.

The value of the materials alone in these reservoirs amounted to more than 70% of their total cost.

* Mexican currency.

Analyses of Estanzuela and San Geronimo Waters.

Table 8 shows analyses of the Estanzuela and San Geronimo waters, made in February, 1910, by Messrs. Ledoux, of New York City. The Estanzuela sample was taken at the valve-house of the South Reservoir, while that of San Geronimo was taken in Shaft No. 1 of the infiltration gallery when flowing at the rate of about 450 liters per sec. Both waters are absolutely free from turbidity.

TABLE 8.—Analyses of Estanzuela and San Geronimo Waters. In Parts per Million.

	Estanzuela.	San Geronimo Infiltration Gallery.
Total solid matter in solution	209.00	305.00
Organic and volatile matter	Not weighable.	Not weighable.
Analysis of Solids:		
Silica	10.5	12.0
Iron and Alumina	Traces.	Traces.
Lime	85.4	112.6
Magnesia	3.8	22.6
Soda (Na_2O)	13.3	20.2
Potash (K_2O)	2.0	1.9
Sulphuric Acid	24.4	41.5
Chlorine	2.0	2.8
Probable Combination of Bases and Acid Radicals in the Solids:		
Silica	10.5	12.0
Iron and Alumina	Traces.	Traces.
Sodium Chloride	3.3	4.6
Potassium Sulphate	3.7	3.5
Sodium Sulphate	26.3	40.8
Calcium Sulphate	13.3	22.1
Calcium Carbonate	142.7	184.8
Magnesium Carbonate	8.4	49.8
	208.2	317.6
Nitrogen as Free Ammonia	0.004	0.032
Nitrogen as Albuminoid Ammonia	0.006	0.022
Nitrogen as Nitrites (N_2O_3)	0.002	0.002
Nitrogen as Nitrates (N_2O_5)	0.100	1.85
Total Hardness (as $CaCO_3$)	155.0	220.0
Alkalinity (as $CaCO_3$)	121.0	180.0

City Water Distribution System.

The distribution system was begun in September, 1906, but the general lay-out of the mains was modified in July, 1907, in view of the division of the system into two services, for high and low pressure. Plate XIX shows in skeleton form the lines of the cast-iron mains. These are laid at the present time along routes containing houses

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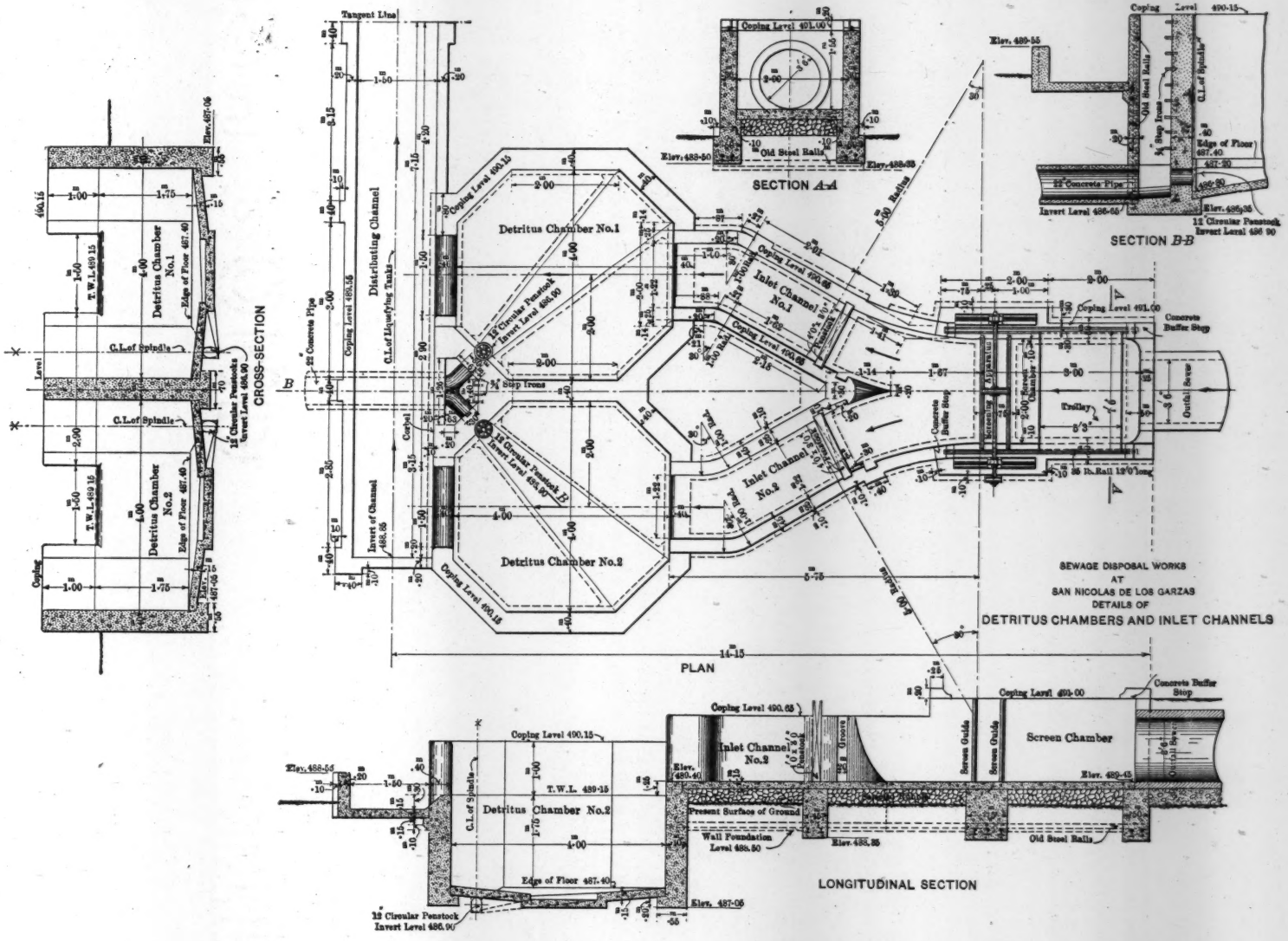


(excluding wooden shacks) which can be served immediately. The distribution system is arranged to serve as follows:

Estanzuela supply	4 150 houses.
San Geronimo supply	8 600 "
Total	12 750 houses.

This represents, at the present time, a division of the city of 32½% for the Estanzuela, and 67½% for the San Geronimo supply. Of the area of the supply district north of Santa Catarina River, 57% will be supplied from San Geronimo and 43% from Estanzuela. The real development of the city, however, is northward in the area of the low-pressure supply.

The static pressure over the city in the two sections varies as follows:

Estanzuela supply	85 to 50 lb.
San Geronimo supply	55 to 29 lb.

The main supply pipe from the South Reservoir is 61 cm. (24 in.) in internal diameter, and this size allows ample provision for future extensions. The supply pipe from the Obispado Reservoir is 76 cm. (30 in.) in internal diameter. On this main, in Calle de Cinco de Mayo, at a distance of 320 m. from the reservoir, has been placed a 76-cm. (30-in.) Venturi meter, the recording apparatus being in the house on the side of the road. Both these supply pipes are carried well into the city, and from them the distribution mains are laid; these are 45.7 and 30 cm. (18 and 12 in.) in internal diameter, with intermediate sections of 15 and 10 cm. (6 in. and 4 in.). Along Calle de Cinco de Mayo, where the division between the two services takes place, two lines are laid, a 30-cm. for high pressure and a 38-cm. (15-in.) for the low pressure. A duplicate pipe, 30 cm. (12 in.) in diameter, is also laid in Calle de Dr. Coss. On Calle de Alvarez the low-pressure pipe is 61 cm. (24 in.), and the high-pressure, 45.7 cm. (18 in.) in diameter. Provision is also made for extending the range of the two services to other districts. Practically every block is provided with gate-valves to cut off the supply in any direction. On the 76-cm. main, 61-cm. (24-in.) valves are used, and are connected by tapers to the pipe. On the 61-cm. mains, 45.7-cm. (18-in.) valves are used. The actual frictional loss by reducing the valve

being small, this method permitted the use of valves of a more convenient size. On all the larger valves there are 15-cm. by-passes fitted with independent gate-valves.

Scour-out pipes, 10 cm. (4 in.) and 15 cm. (6 in.) in diameter, are placed in various parts of the system, draining to the sewers. Air-valves, both double and single, are also placed at high points in different parts of the system.

Reducing Valves.—At four points in the system the mains are arranged so that the supply can be interchangeable. Fig. 15 shows the arrangement of the mains at the junction of Cinco de Mayo and Alvarez Streets, and is typical of the arrangement at the other points.

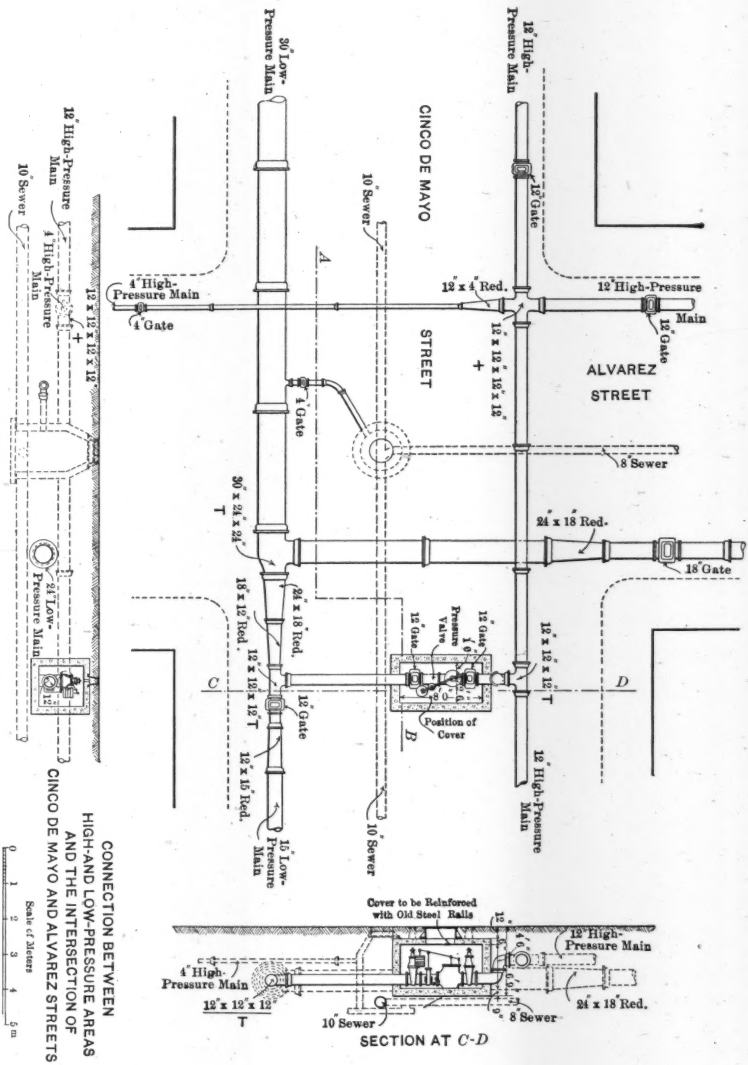
Each reducing valve is placed on a 30-cm. (12-in.) branch main between the two services. These valves adjust themselves automatically to the pressure required, after they have been properly regulated to the different pressures on either side. To allow repairs to be easily made, there are ordinary gate-valves at each end enclosed in the same pit. If necessary, as in case of fire, any part of the system can be changed into high pressure temporarily by closing the valves against the San Geronimo supply.

Table 9 gives the length of the mains as laid, and the number of valves.

TABLE 9.—LENGTH OF WATER MAINS.

DIAMETER:		Length, in meters.	Number of gate-valves.
Centimeters.	Inches.		
10.2	4	49 831.68	677
15.2	6	31 918.31	306
30.5	12	14 461.31	117
38.1	15	1 661.98	11
45.7	18	4 522.61	5
61.0	24	2 826.54	10
76.2	30	1 454.40	...
Totals.....		106 676.83	1 126

The pipes were all cast according to the British Standard Specification, in 3.65-m. (12-ft.) lengths, and were supplied by Messrs. D. Y. Stewart and Company, and Messrs. Dick, Kerr and Company, of Kilmarnock and London. The valves were all of standard design, faced with gun-metal, and were supplied by Messrs. Glenfield and Kennedy, Limited, of Kilmarnock, Scotland.



CONNECTION BETWEEN HIGH-AND LOW-PRESSURE AREAS AND THE INTERSECTION OF CINCO DE MAYO AND ALVAREZ STREETS

Fig. 15.

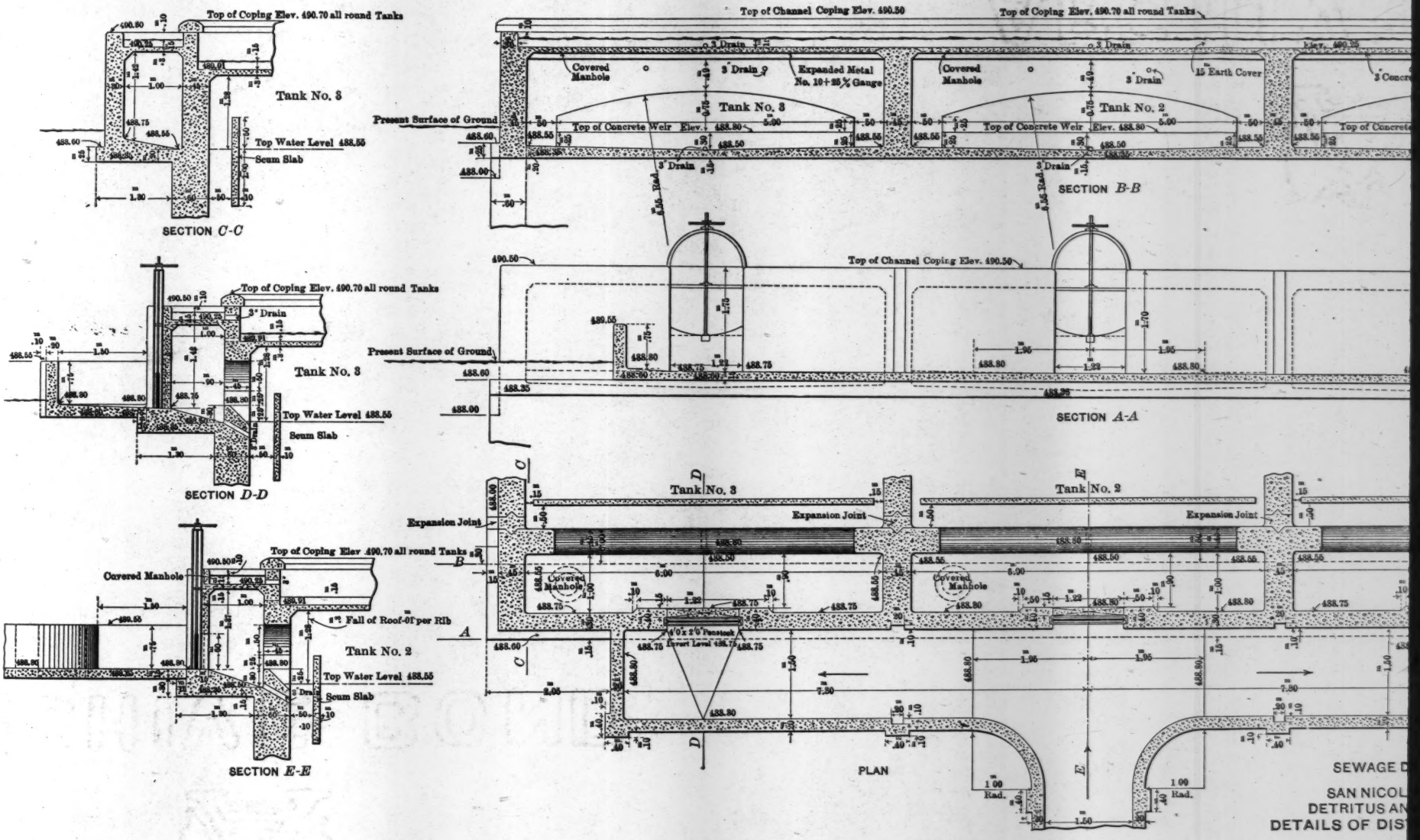
In the distribution system it is proposed to provide 200 fire-hydrants, by arrangement with the municipality, but only a few of these have been placed. The general type is a double hydrant for two 63.5-mm. (2½-in.) streams. These are to be placed at the corner of every block in the business portion of the city; single-way hydrants will be used in the residential districts.

Laying Cast-Iron Pipes.—Table 10 has been prepared to show what can be accomplished with Mexican labor in laying pipes. In this kind of work the labor was particularly efficient; after the gangs were once drilled into shape, the work proceeded systematically, and at very good speed. All the pipes, after being laid, were tested to 150 lb. per sq. in. in the presence of the Technical Inspector.

Table 11 gives the details of the excavation, the material, and the average cost, of laying about 106.6 km. of pipes.

House Connections.—The ordinary house connections, which are of 19-mm. (¾-in.) galvanized-steel pipe, are connected to the mains by lead goosenecks and brass corporation cocks. The Company's obligation under the concession extended to the edge of the sidewalk, and at this point curb-boxes, chiefly of the Hays pattern, were placed; but, subsequently, owing to the metering of every house service in the city, the control of the Company extended to the meter, which, as a rule, is placed immediately inside of the house. Owing to the rapid deterioration of the house service pipes in some districts of the northern part of the city, where the soil is formed of decaying organic matter, it has been decided to use lead pipe entirely from the main to the meter.

Damage Due to Floods.—During the night of August 27th, the main 61-cm. pipe, under the river bed of Santa Catarina, at the point where the main entered the city, was destroyed for a distance of 130 m., due to the scouring away of a whole block of city property. The Venturi meter register chart at the South Reservoir showed that the break occurred a few minutes before midnight. The location of this pipe is shown by Fig. 5; its broken end was in proximity to an old bridge pier. Fortunately, at the time of the flood, the Obispado Reservoir works were completed, and the whole city was supplied with water from San Geronimo within 48 hours. As only about 1 500 services had then been connected, this delay was not serious; in fact, in the lower part of the city, the water in the mains was sufficient until the San Geronimo supply could be connected. To make a temporary con-


Top of Coping Elev. 490.70 all round Tanks
Tank No. 3
Top Water Level 488.55
Scum Slab
SECTION C-C
Top of Channel Coping Elev. 490.50
Top of Coping Elev. 490.70 all round Tanks
3" Drain
Covered Manhole
Expanded Metal No. 10+25% Gauge
Tank No. 3
Tank No. 2
Present Surface of Ground
Top of Concrete Weir Elev. 488.80
15" Earth Cover
SECTION B-B
Top of Coping Elev. 490.70 all round Tanks
Tank No. 3
Top Water Level 488.55
Scum Slab
SECTION D-D
Top of Channel Coping Elev. 490.50
Present Surface of Ground
SECTION A-A
Top of Coping Elev. 490.70 all round Tanks
Covered Manhole
Tank No. 2
Top Water Level 488.55
Scum Slab
SECTION E-E
Tank No. 3
Tank No. 2
Expansion Joint
Covered Manhole
4'0" x 2'0" Penstock
Invert Level 486.75
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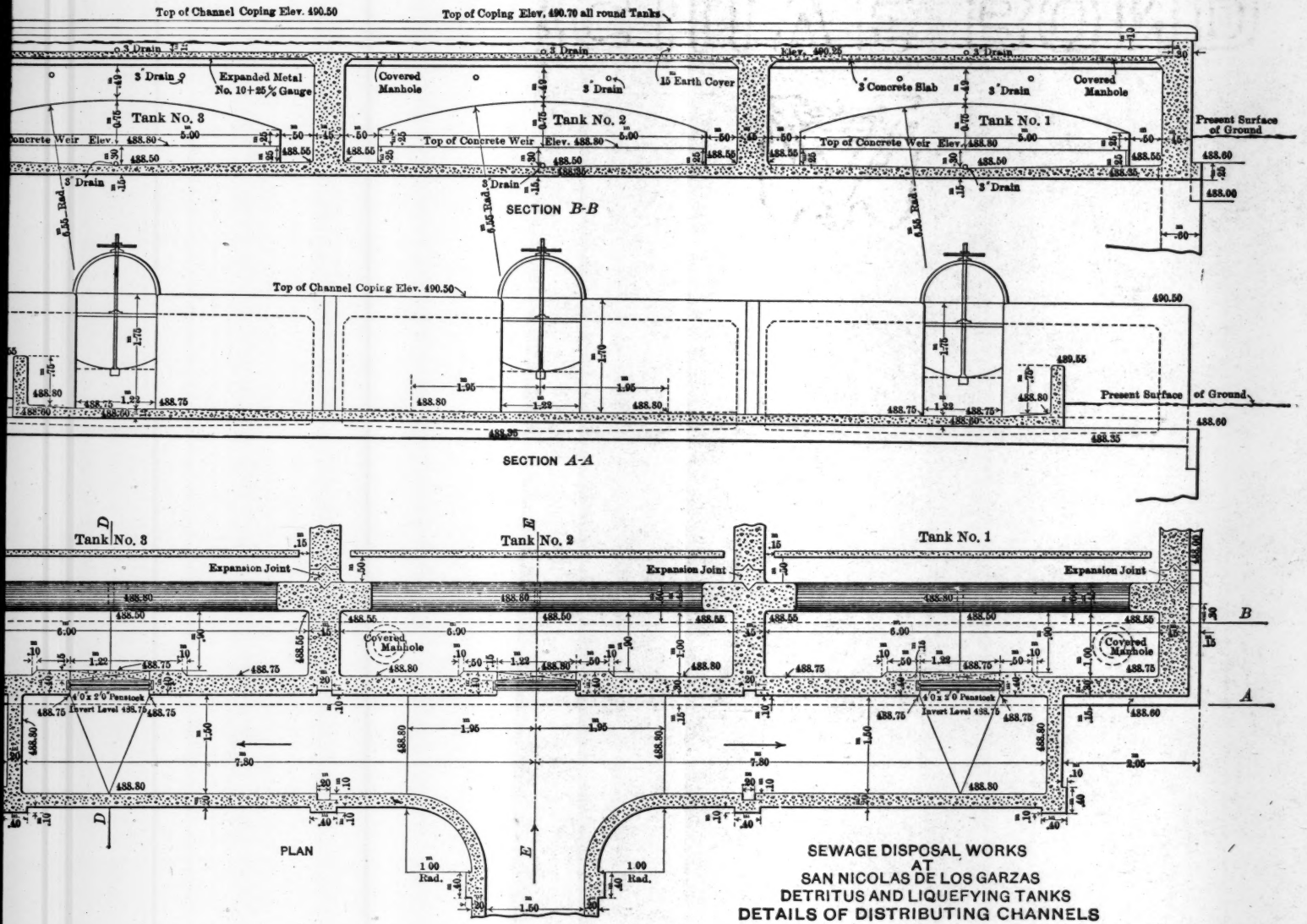


SEWAGE DISPOSAL WORKS
AT
SAN NICOLAS DE LOS GARZAS
DETRITUS AND LIQUEFYING TANKS
DETAILS OF DISTRIBUTING CHANNELS

TABLE 10.—Cost of Laying and Jointing Cast-Iron Pipes, Excluding Lowering and Testing.

Employees.	Rate for 10-hour day. Pesos.	76 Cm. (30 in.)			61 Cm. (24 in.)			50 Cm. (20 in.)			45.7 Cm. (18 in.)		
		No. of men.	Total cost of labor. Pesos.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.
Foreman	4.50	1	4.50	.....	1	4.50	.....	1	4.50	.....	1	4.50	.....
Caulkers	3.00	4	12.00	.....	4	15.00	.....	4	12.00	.....	4	12.00	.....
Lead pourers	2.00	2	4.00	.....	2	4.00	.....	2	4.00	.....	2	4.00	.....
Lead melter	1.50	1	1.50	20	1	1.50	25	1	1.50	35	1	1.50	40
Pipe cutter	2.00	1	2.00	0.498	1	2.00	0.410	1	2.00	0.387	1	2.00	0.221
Peons	1.00	12	12.00	.....	10	10.00	.....	12	12.00	.....	8	8.00	.....
Water boy	0.50	1	3.50	.....	1	0.50	.....	1	0.50	.....	1	0.50	.....
	.....	22	36.50	.....	21	37.50	.....	22	36.50	.....	18	32.50	.....

Employees.	Rate for 10-hour day. Pesos.	38 Cm. (15 in.)			30.5 Cm. (12 in.)			15 Cm. (6 in.)			10 Cm. (4 in.)		
		No. of men.	Total cost of labor. Pesos.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.	No. of men.	Total cost of labor.	No. of pipes laid.
Foreman	4.50	1	4.50	.....	1	4.50	.....	1	4.50	.....	1	4.50	.....
Caulkers	3.00	4	12.00	.....	4	12.00	.....	4	12.00	.....	4	12.00	.....
Lead pourers	2.00	2	4.00	.....	2	4.00	.....	2	4.00	.....	2	4.00	.....
Lead melter	1.50	1	1.50	45	1	1.50	60	1	1.50	100	1	1.50	150
Pipe cutter	2.00	1	2.00	0.196	1	2.00	0.147	1	2.00	0.062	1	2.00	0.0574
Peons	1.00	8	8.00	.....	8	8.00	.....	6	6.00	.....	6	6.00	.....
Water boy	0.50	1	0.50	.....	1	0.50	.....	1	0.50	.....	1	0.50	.....
	.....	18	32.50	.....	18	32.50	.....	16	30.50	.....	16	30.50	.....

TABLE 11.—Cast-Iron Water Pipes.—Cost of Materials and Laying at Monterrey.

Materials per Standard Length of Pipe.

Diameter of Pipe:		Thickness, in millimeters.	Weight of pipe, in kilogrammes.	Cost per piece, f.o.b. Monterrey, in pesos.	Lead:		Oakum:	Charcoal:	Total cost of material per linear meter, in pesos.
Centimeters.	Inches.				Weight, in kilogrammes.	Cost, in pesos.	Cost, in pesos.	Cost, in pesos.	
10	4	10.3	109	11.65	2.0	0.37	0.025	0.0525	3.30
15	6	11.1	163	15.74	3.7	0.67	0.0675	0.065	4.51
30.5	12	15.8	463	76.50	7.9	1.44	0.1225	0.10	21.35
38	15	17.4	680	79.36	10.6	1.94	0.175	0.12	22.30
45.7	18	19.0	871	90.28	13.4	2.42	0.2375	0.1375	25.42
61	24	22.2	1 261	117.60	18.8	3.42	0.335	0.175	33.20
76	30	25.4	1 946	199.05	24.5	4.42	0.44	0.2125	55.77

Labor.

Diameter of Pipe:		Width of trench, in meters.	Depth, in meters.	Cubic meters per linear meter.	Cost of excavation per linear meter. Pesos.	Back-filling and removing surplus. Pesos.	Total cost, excavation, back-filling, etc. Pesos.	Hauling per linear meter:		Cost of laying, per linear meter. Pesos.	Total hauling and laying, per linear meter. Pesos.	Total excavation and laying, labor, complete, per linear meter. Pesos.
Centimeters.	Inches.							Hauling. Pesos.	Miscellaneous. Pesos.			
10	4	0.55	0.90	0.50	0.60	0.18	0.78	0.0275	0.005	0.06	0.0925	0.8725
15	6	0.60	1.00	0.60	0.72	0.22	0.94	0.45	0.005	0.825	0.1325	1.0725
30.5	12	0.65	1.20	0.78	0.94	0.29	1.23	0.18	0.0075	0.1475	0.335	1.565
38	15	0.70	1.30	0.91	1.10	0.34	1.44	0.2725	0.01	0.19	0.4775	1.9125
45.7	18	0.80	1.40	1.12	1.34	0.41	1.75	0.2725	0.01	0.245	0.5275	2.2775
61	24	1.00	1.50	1.50	1.80	0.55	2.35	0.825	0.08	0.41	1.315	3.665
76	30	1.10	1.60	1.76	2.11	0.65	2.76	0.83	0.10	0.53	1.46	4.22

Note.—The above costs of earthwork are based on the following rates and percentages over the whole city:

Earth, per cubic meter	0.35 pesos	50%
Soft sillar	0.75 "	20%
Hard sillar	1.50 "	20%
Rock (chiefly conglomerate)	4.00 "	10%

Summary of Table 11.

Diameter of Pipe:		Total labor cost, in pesos.	Materials. Pesos.	Total cost per linear meter, in pesos.
Centimeters.	Inches.			
10	4	0.8725	3.30	4.1725
15	6	1.0725	4.51	5.5825
30.5	12	1.565	21.35	22.915
38	15	1.9125	22.30	24.2125
45.7	18	2.2775	25.42	27.6975
61	24	3.665	33.20	36.865
76	30	4.22	55.77	59.99

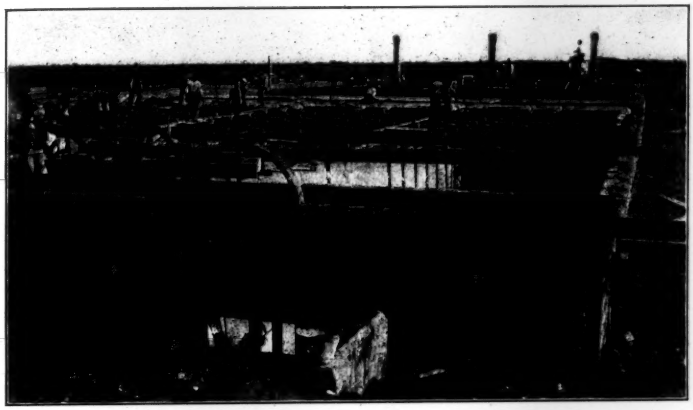


FIG. 1.—CAST CONCRETE BEAMS BEING PLACED IN POSITION, LIQUEFYING TANKS.

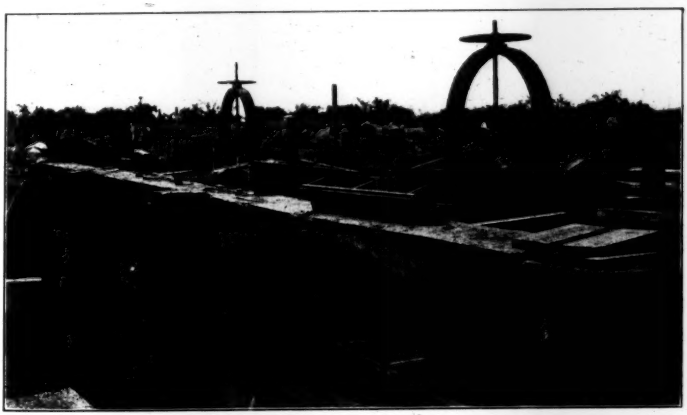


FIG. 2.—INLET WEIRS TO LIQUEFYING TANKS, DURING CONSTRUCTION.

nection to conduct the high-pressure water to the city, a 15-cm. steel pipe was placed above ground, on the line of the main, for a distance of 100 m. This pipe was supported by a cable, 30 mm. in diameter, and by timber trestles. By limiting the supply district, this pipe was of sufficient capacity to serve until the large main could be safely restored.

The flood destroyed about 1 200 houses in the neighborhood of the river. In a number of blocks the smaller mains were scoured away, but considerable salvage was done afterward, and, as it is the intention of the authorities not to permit rebuilding along the flood-path of the river, these mains do not require reconstruction.

Main Sewerage System.

The Company's obligations, as far as drainage is concerned, were limited to the removal and disposal of sewage, no provision being required for storm-water, which is allowed to find its way to the natural watercourses. Apart from that fact, however, the best system for a city like Monterrey, where rainfall for many months at a time is very scarce, is the strictly "separate system." In the design advantage was taken of the natural topography of the drainage district, which is almost an ideal one for a gravitation system of sewers, the general fall in all directions being northeast; it was also in this direction that the best available land could be obtained for disposal purposes.

Plate XX shows in skeleton form the general lay-out of the sewers. Two drainage districts are arranged, divided by Calle de Washington, which may be regarded as practically the center of the city, and each of these districts has an independent main collector connecting to the outfall sewer at the northeast extremity of the city.

The system has been designed so that extensions may be made and may cover any part within the city limits; the main collectors are large enough for the whole area when fully built up.

The sewers are designed on a very liberal basis, namely, on the assumption that when flowing half full the quantity to be dealt with will be 380 liters per capita per day, with a maximum rate of flow of 200 per cent. It was assumed that each house would be occupied by 7 persons and have a frontage of 12½ m. The minimum velocities in the sewers, when running full, vary between 0.91 and 1.5 m. per sec., with the exception of a few blocks.

The minimum size adopted was 24.3 cm. (8 in.) in internal diameter. The sewers of diameters between 24.3 and 50 cm., are 0.91 m. (36 in.) long, and are of salt-glazed vitrified clay, imported from San Antonio, Tex.

Table 12 gives the details of the length of the various sewers laid.

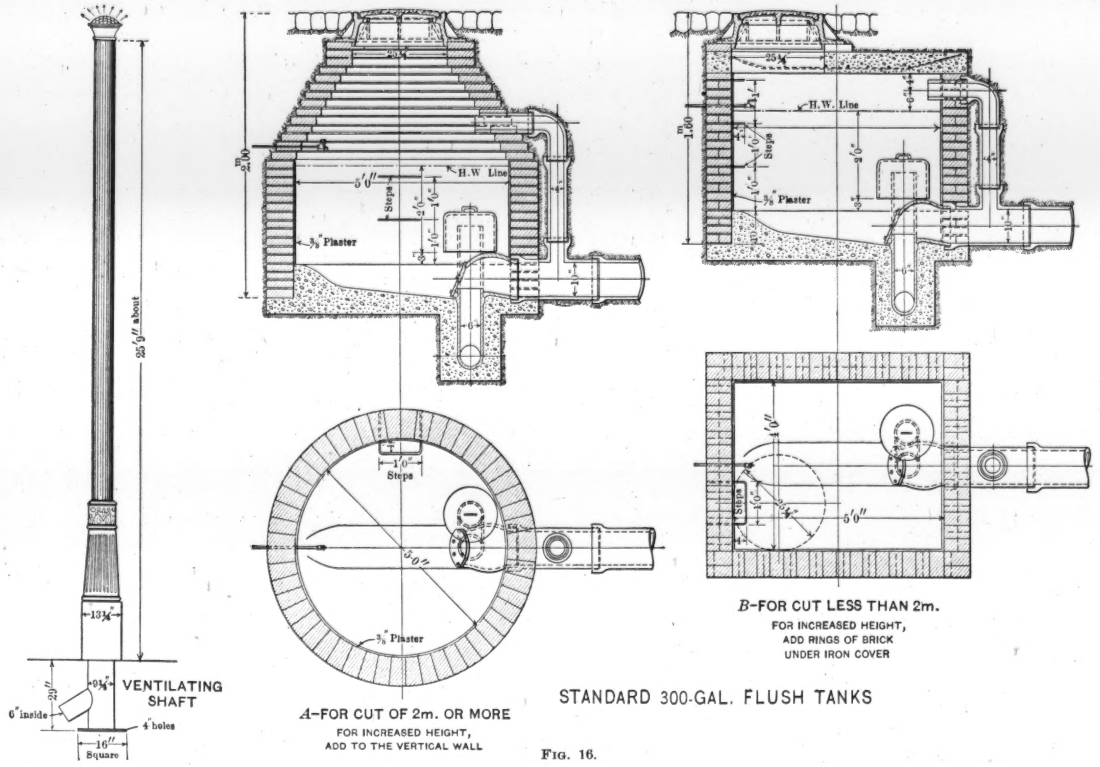
TABLE 12.—LENGTH OF SEWERS.

DIAMETER:		Kind.	Length, in meters.
Centimeters.	Inches.		
24.3	8	Fire-clay	38 332.85
25.4	10	"	16 400.69
30.5	12	"	7 953.15
38.1	15	"	4 850.56
45.7	18	"	2 023.40
50.8	20	"	1 450.53
55.9	22	Reinforced concrete tubes, 6.9 cm. thick	3 134.20
61.0	25	" " " 7.6 " "	357.40
68.6	27	Brick and concrete	484.05
76.2	30	" " "	662.69
		Total.....	75 649.15

The greater number of the manholes are of brickwork, 23 cm. thick, and have concrete inverts. They have a diameter of 1.2 m., which is reduced to 0.61 m. at the top, and each is provided with a heavy cast-iron frame and closed cover weighing about 190 kg. There are 521 manholes, and they are placed at every block and on long lines about 80 m. apart.

The sewers are flushed with 15-cm. (6-in.) automatic flushing siphons of the Miller pattern with 20-cm. (8-in.) discharge pipes. There are 278 of these siphons, and they are placed in flush-tanks (Fig. 16) built of brickwork and plastered with 1:1 cement mortar. Their capacity varies from 800 to 1 200 liters, and they discharge from 22½ to 28½ liters per sec. They are timed to flush once in 24 hours.

The system is at present ventilated by 23-cm. (9-in.) steel ventilating columns (Fig. 16), with ornamental cast-iron bases. There are 220 of these columns. Most of them are 7.85 m. above the level of the edge of the sidewalk, and are connected to special 15-cm. branch pipes leading from the sewer on the outside of the flush-tanks. In the center of the city they are provided with extension lengths, giving a total height of 12 m.



STANDARD 300-GAL. FLUSH TANKS

FIG. 16.

Table 13 gives the particulars of the average distributed cost of laying the 75.6 km. of sewers.

TABLE 13.—AVERAGE COST, PER LINEAR METER, FOR 75.6 KM. OF SEWERS, FOR MATERIALS AND LABOR COMPLETE.

Kind of Sewer.	Internal Diameter of Sewers.		Cost of materials, including 10-cm. (4-in.) branches every 4½ m. Pesos.	Earthwork and Labor:			Total cost of sewer complete, per linear meter. Pesos.
	Centimeters.	Inches.		Average depth of sewer, in meters.	Cost of excavation, including back-filling, removing surplus, etc. Pesos.	Cost of labor in laying (including hauling, etc.). Pesos.	
Fire-clay	24.3	8	2.00	2.10	3.46	0.21	5.67
"	25.4	10	2.78	2.25	3.97	0.2625	7.0125
"	30.5	12	3.64	2.50	4.705	0.305	8.65
"	38.1	15	6.14	2.75	5.50	0.4375	12.0775
"	45.7	18	8.80	3.00	6.745	0.645	16.19
"	50.8	20	11.30	3.50	8.275	0.815	20.39
Concrete	55.9	22	5.93	3.50	9.19	1.325	16.445
"	61.0	25	7.30	3.75	11.245	1.685	20.23
One brick thick on concrete foundations	68.6	27	7.17	3.75	11.735	3.93	22.835
	76.2	30	7.925	4.00	14.53	4.515	26.97

The house connections are chiefly of 10-cm. (4-in.) pipes, laid on a minimum gradient of 2½%, from oblique branches on the sewer to siphon intercepting traps near the house, as shown by Fig. 17. From this trap a 10-cm. fire-clay inspection pipe is carried up and capped at the sidewalk level with a cast-iron box having a locked cover. From this inspection pipe a branch is connected to a cast-iron fresh-air inlet, in most cases set in the wall of the house, the inlet being 30 cm. above the level of the pavement.

Effect of the Flood on Sewers.—The flood of August 27th and 28th, 1909, partly destroyed one of the main collectors, which was laid along the banks of the river and encased in concrete. This has now been relaid farther north, and out of the way of any future floods. The total length of the new sewers replacing those damaged amounts to 1 200 m., and they vary in internal diameter from 20 to 55.9 cm. (8 to 22 in.).

MAIN OUTFALL SEWER.

The direction of the main outfall sewer was determined after a thorough study of all the available land lying to the north and north-east of the city, as it was the intention of the Company to utilize

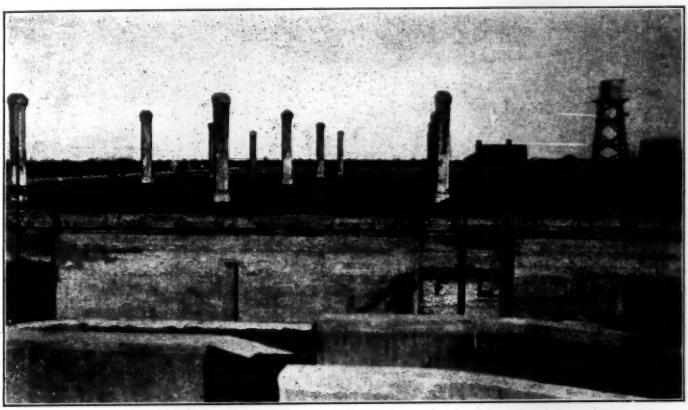


FIG. 1.—VIEW OF LIQUEFYING TANKS, FROM INLET END.

FIG. 2.—VIEW OF SANTA CATARINA RIVER IN FLOOD, ON AUGUST 28TH, 1909.

for irrigation purposes the sewage and any surplus waters that might be developed. The best available site was found to be about 12 km. north of the city, a little northwest of the village of San Nicolas de los Garzas, as shown on Plate II. The long length of outfall required was justified by the cheap cost of the land and its excellent char-

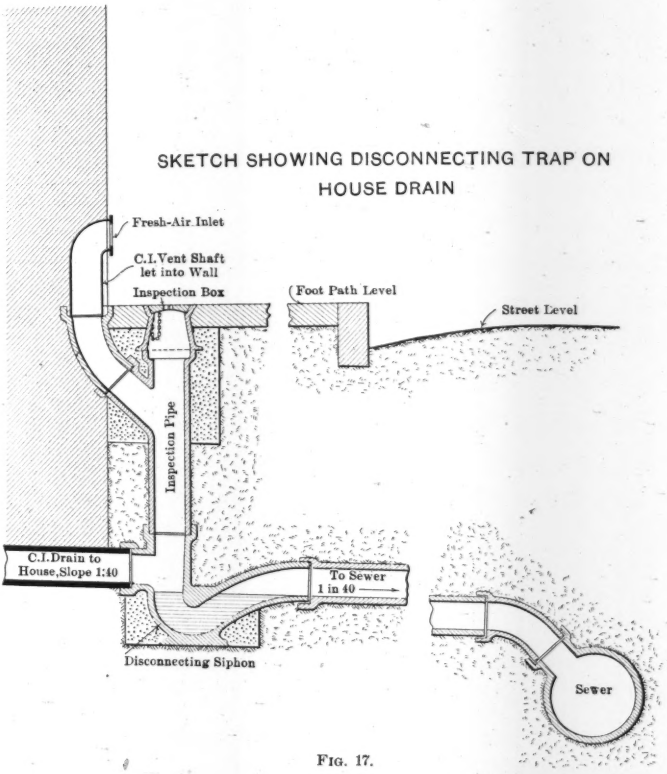


FIG. 17.

acter for sewage irrigation. The sewer was designed for a capacity of 90 000 000 liters a day (36.76 cu. ft. per sec.) in order to allow for conveying surplus waters as well as sewage.

The outfall intercepts the two main branches of the city sewers at Calle de Allende and Calle de Tapia, and its total length is approxi-

mately 11 900 m. The chief type adopted is shown on Plate XXII. It is formed with an invert of radial bricks laid in 1:2 cement mortar, on a foundation of 1:3:5 concrete approximately 7 cm. thick. As the ground was chiefly in hard sillar, only a little concrete was required to mould the bottom to the correct shape. The arch was formed of special radial bricks, 15 cm. (6 in.) deep, laid in cement mortar. These bricks were adopted in preference to concrete, owing to the heavy cost of sand and rock, due to the long haul, and for the purpose of obtaining rapid work. Plate XXI shows the sewer arch, and one of the ventilating columns and manholes. The bricks were obtained from the local brick plant, and form a very satisfactory material for sewers, being well burnt, thoroughly hard, and absorbing not more than 7½% of their weight of water. The contract prices for the labor on the brickwork were 1.25 pesos per sq. m., and 1.38 pesos for the arch.

The general route of the sewer is very direct, long straight lines of several kilometers being possible, and these were joined by curves of approximately 30 m. radius. The gradient of the sewer invert is 0.2% (1 in 500) which is approximately the general fall of the ground northward from Monterrey.

The total quantity of excavation was as follows:

No. 1, soft earth	8 960	cu. m.
No. 2, sillar	18 492	" "
No. 3, conglomerate rock	9 822	" "
Total	37 274	cu. m.

The contract prices for this excavation were: for No. 1, 32 cents; No. 2, 85 cents; and No. 3, 2.17 pesos per cu. m.

All the excavation was in perfectly dry ground. Where the sewer was partly out of the ground it had a foundation of concrete, 1.75 m. wide, from 15 to 23 cm. thick, below the bottom of the brickwork, and carried up to the springing of the arch, and a well-tamped embankment, with slopes of 1½ to 1, to protect the sewer to a height of 30 cm. (12 in.) above the arch. For 342 m. at the Monterrey end of the line, the sewer was constructed in tunnel, from the open end and from two intermediate shafts. The tunnel throughout was in sillar, and the contract price for excavation was 24.50 pesos per lin. m. This work was done without timbering of any kind, except at the shaft lengths. Plate XXII shows

PLATE XXIX.
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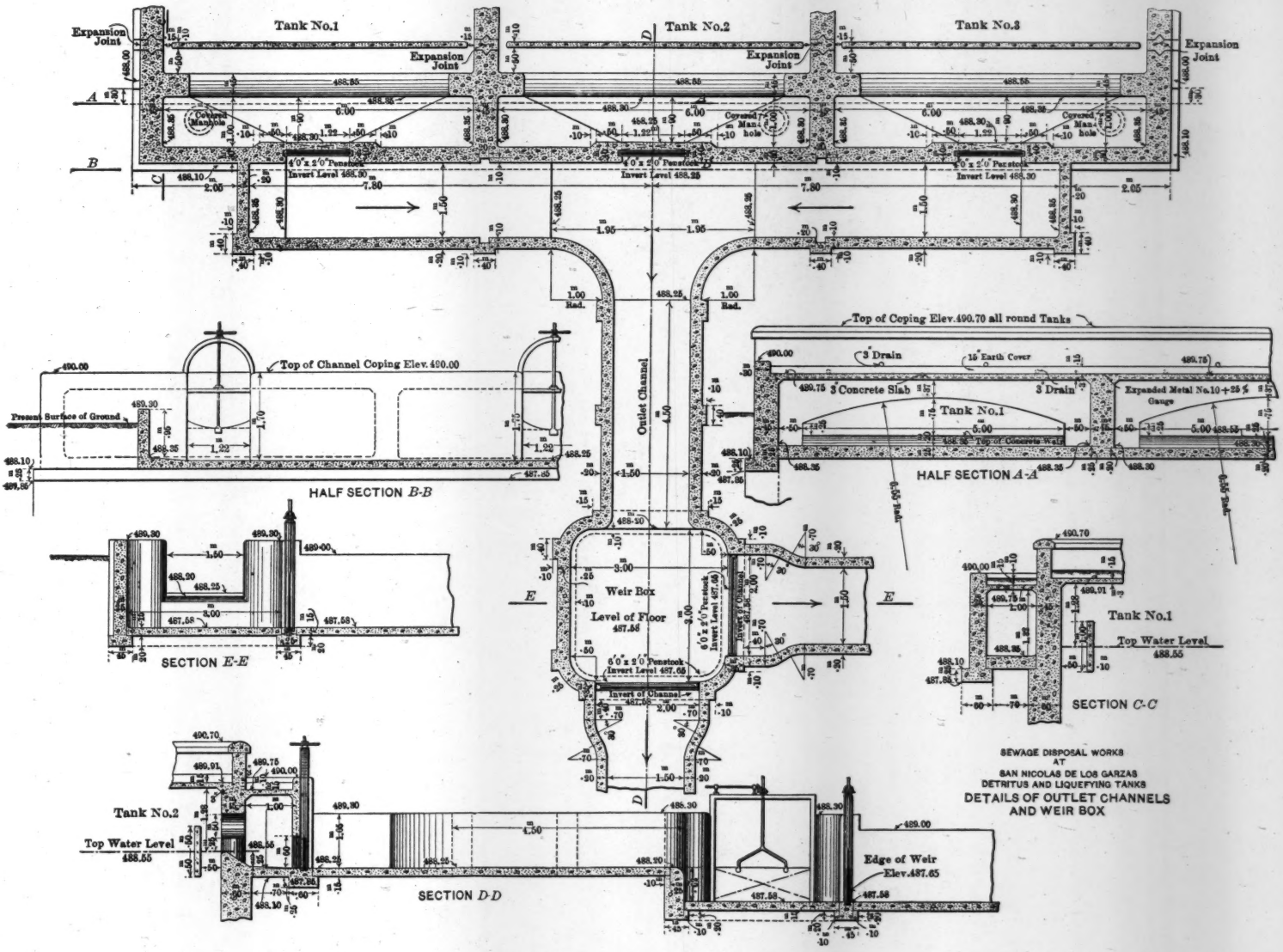
CONWAY ON
WATER-WORKS AND SEWERAGE OF MONTERREY.



SEWAGE DISPOSAL WORKS
AT
SAN NICOLAS DE LOS GARZAS
DETRITUS AND LIQUEFYING TANKS
DETAILS OF OUTLET CHANNELS
AND WEIR BOX

the lining of the tunnel, which was of concrete with a brick invert. At four places the sewer passes under main railway tracks, which at these points were carried on steel girders supported on concrete abutments, the sewer being carried under the tracks in the ordinary way.

Bridges.—At three points the sewer was carried over arroyos on reinforced concrete girders. No. 1, at Station 5 600, consisted of four 10-m. spans; No. 2, at Station 8 365, over the Estanscia Arroyo, consisted of nine 10-m. spans; and No. 3, at Station 8 960, over the Topo Chico Arroyo, consisted of three 10-m. spans. One of these bridges is shown on Plate XXIII. They were designed as two parallel continuous girders with connecting top and bottom slabs. The concrete for the girders was a 1:2½:3½ mixture, the sand being from the crusher and the rock gauged to pass a 19-mm. (¾-in.) screen. The inside was rendered with a coat of 1:1 cement mortar, 7 mm. thick, for watertightness.

The piers of the Estanscia Bridge (Plate XXIII) were carried down through soft earth to a stiff clay from 4½ to 6 m. below the surface, and the foundations were spread so that the pressure would not exceed 1 ton per sq. ft. The ends of the bridges were protected by rubble wing-walls supporting the embankment over the sewer. A 1:3:5 concrete was used for the upper part of the piers, and the lower part was of the same mixture with 30% of large boulders. There are 70 manholes (Fig. 19) along the line of the sewer, and they vary from 150 to 230 m. apart. The sewer is ventilated with 30 concrete towers (Fig. 18, and Fig. 2, Plate XXI), 2.9 m. high, having 20-cm. (8-in.) shafts.

The works for the outfall sewer were carried out satisfactorily under a contract with Mr. John Phillips, of Mexico City, the Company supplying the greater part of the materials. The work was begun on March 16th, and finished on November 12th, 1908.

Sewage Disposal Works and Irrigation Lands.

For the purpose of disposing of the sewage and using it profitably, the Company purchased 909 hectares (2 246 acres) of land from the Community of San Nicolas de los Garzas, the outfall sewer being carried to the southwestern boundary of the land acquired. This area has a general fall in all directions to the northeastern boundary, with a gradual fall of about 25 m. across the diagonal of the land. The area purchased was practically virgin land, only small portions having

been cultivated. The greater part was covered with a growth of mezquite trees and small shrubs. The quality of the land is excellent, if properly irrigated, and capable of yielding abundant crops of every description. The limits of this land are shown on Plate II.

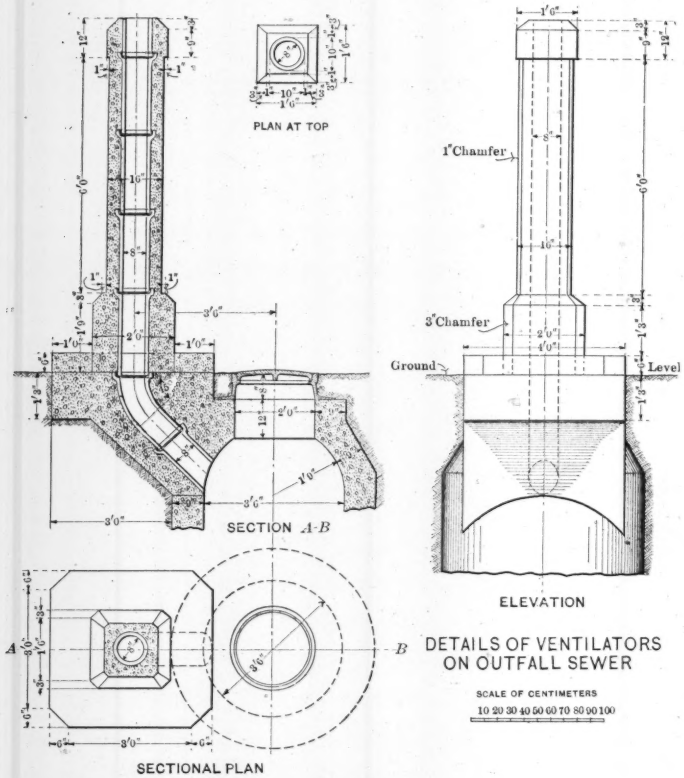


FIG. 18.

Sewage Purification Tanks.—For the purpose of obtaining a satisfactory effluent to discharge on the land without causing nuisance, the Company built a system of detritus chambers and liquefying tanks at the end of the outfall sewer. One difficulty to be faced, in designing these works, was the fact that there were no data regarding the probable quantity of dry-weather sewage, nor any particulars as to its general

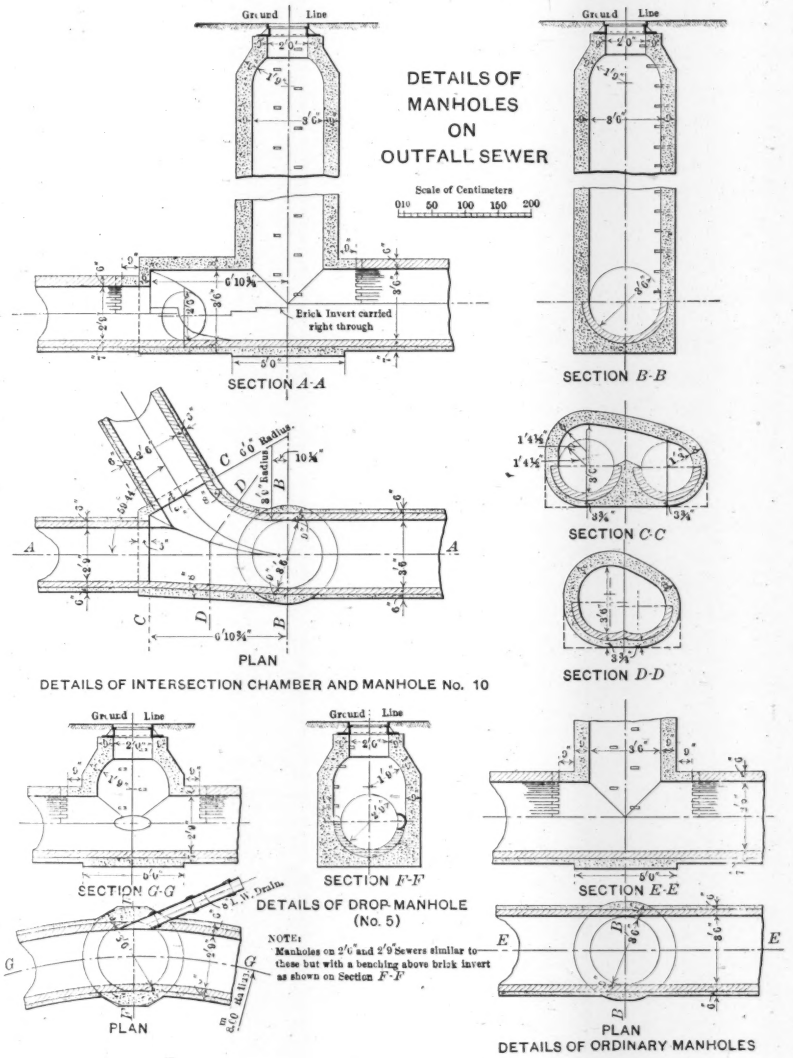

DETAILS OF MANHOLES ON OUTFALL SEWER
Scale of Centimeters
0 10 50 100 150 200
Ground Line
Brick Invert carried right through
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
PLAN
DETAILS OF INTERSECTION CHAMBER AND MANHOLE No. 10
SECTION F-F
SECTION G-G
DETAILS OF DROP MANHOLE (No. 5)
NOTE: Manholes on 2'0" and 2'9" Sewers similar to these but with a benching above brick invert as shown on Section F-F
SECTION E-E
PLAN
DETAILS OF ORDINARY MANHOLES

FIG. 19.

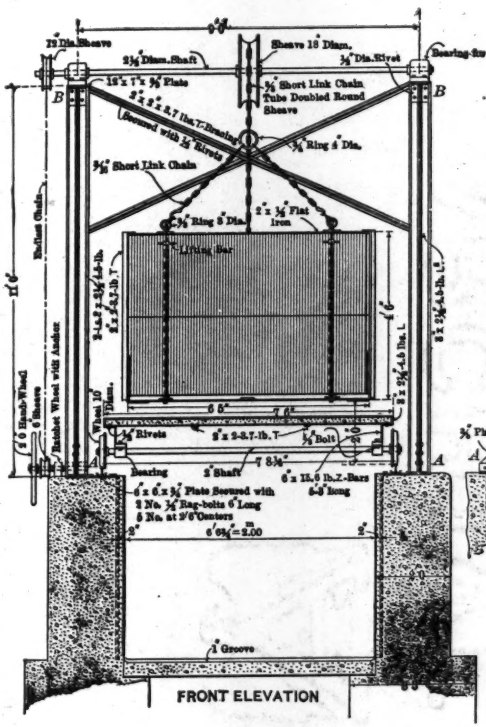
character; there was also the probability that the outfall sewer would have to carry large quantities of surplus water. Therefore, the system was designed so as to be capable of extension if necessary, and the sizes of the various tanks were limited at present, because of the septic processes which would be set up in the long length of outfall sewer. The tanks were designed to deal with 10 000 000 liters of sewage proper per day, and the channels, etc., were proportioned to take the full flow of the sewer if necessary. Provision was also made for discharging large volumes of surplus water directly on the land, independent of the tanks. To do this a by-pass was taken from the sewer a short distance before reaching the site of the tanks. By properly timing the flow, arrangements could be made to discharge these waters in the early hours of the morning, by allowing the scour-pipes in the distribution system to be opened at night when the domestic sewage flow was at its minimum. As the area of land available is very great, the degree of purification in the tanks was relatively unimportant; the object to be obtained consisted chiefly in distributing on the land an effluent which would be innocuous and clear.

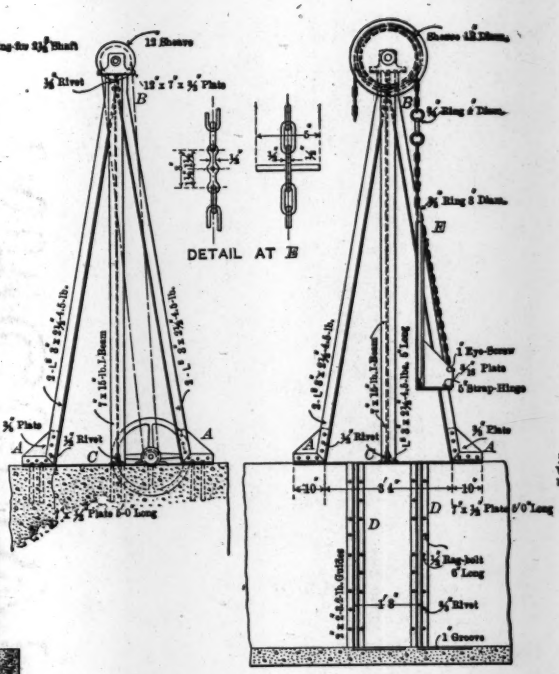
The general design of the works is shown on Plate XXIV, and they consist essentially of a screen chamber, duplicate detritus tanks, and three liquefying tanks. There is also a sludge-pit 629 m. from the tanks.

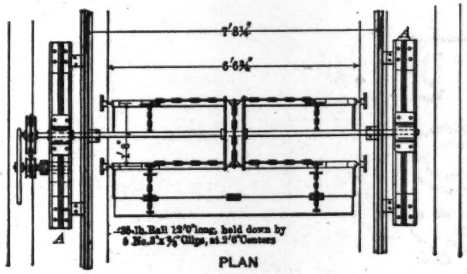
Screen Chamber and Detritus Tanks.—Enlarged details of the screen chamber are shown on Plate XXV. The invert, where the sewer enters the screen chamber, is 489.45 m. above datum. This chamber has duplicate screens which are fully detailed on Plate XXX. For cleaning purposes the screens are raised by a steel-framed head-gear, which is arranged so that they may be lowered to a small traveling bogie, out of the way of the screen chamber.

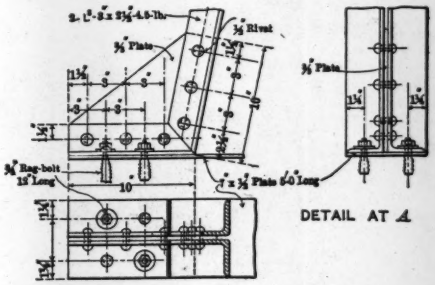
From the screen chamber there are two main channels, 1.22 m. wide, branching to the two concrete detritus chambers. Each channel has a square penstock, so that the sewage can be diverted into either chamber when necessary.

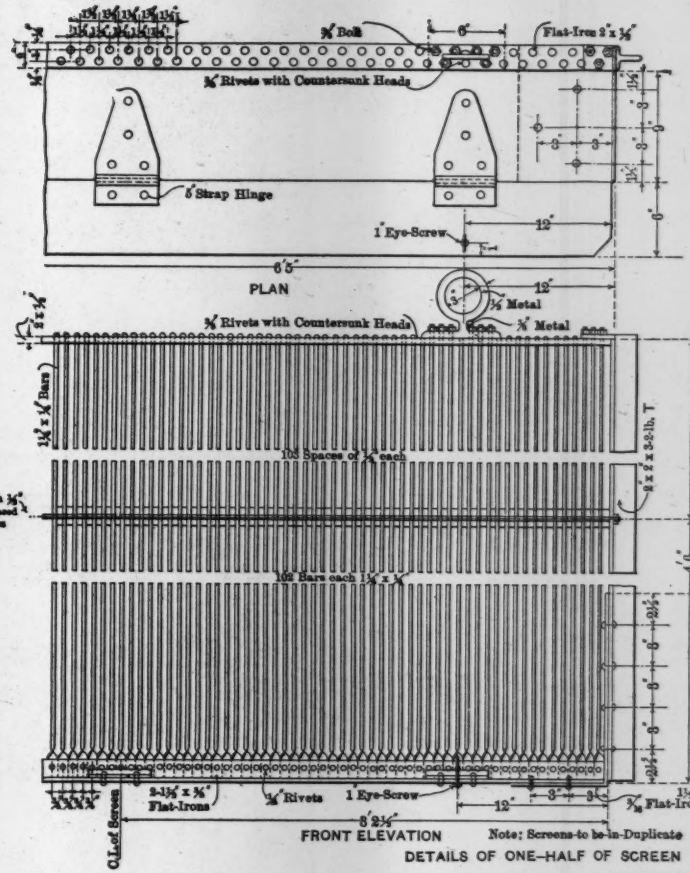
The detritus chambers are octagonal in plan, 4 m. in diameter, and each is provided with an outlet weir 1.50 m. wide. At the weir level the chambers have a depth of 1.75 m., with drainage channels below that level. The coping is 1 m. above the outlet weir of the detritus tanks. To drain off these chambers, each has a scour-out pipe, 30 cm. in

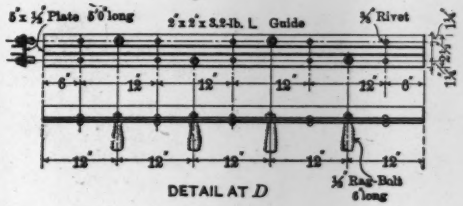












SEWAGE DISPOSAL WO
AT
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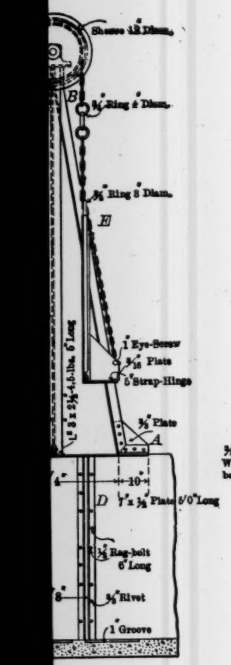
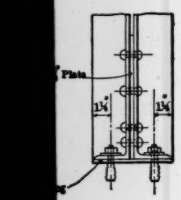
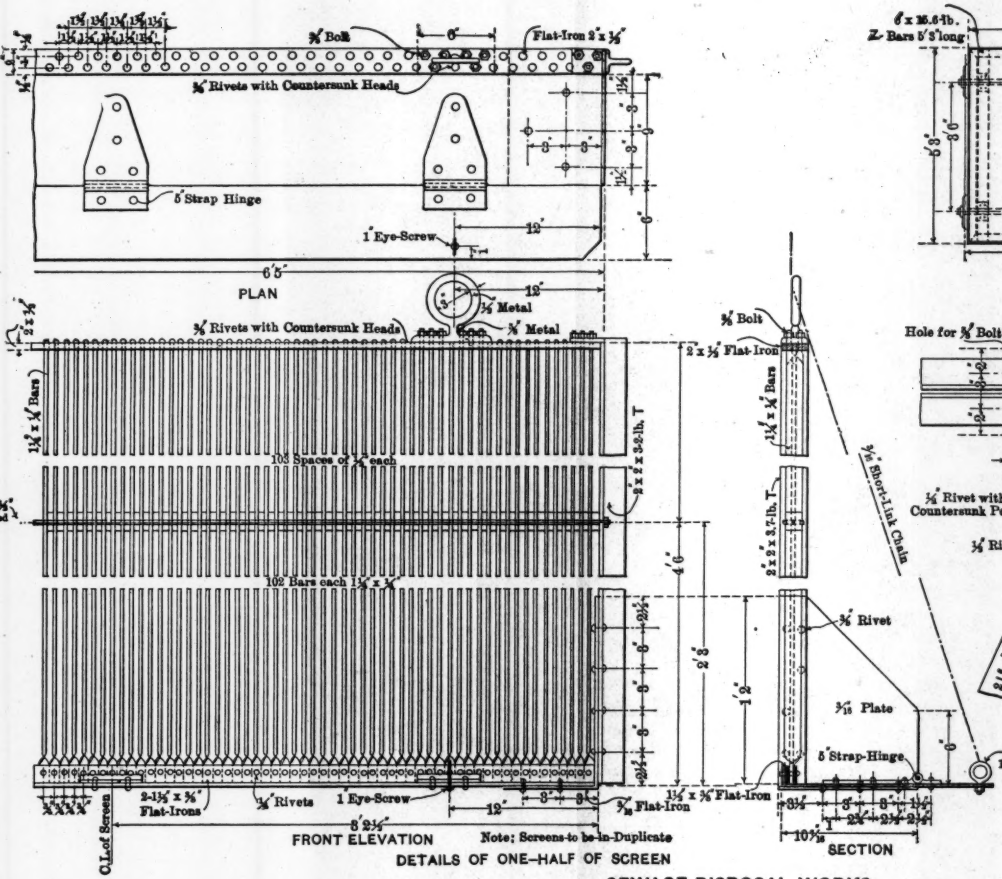
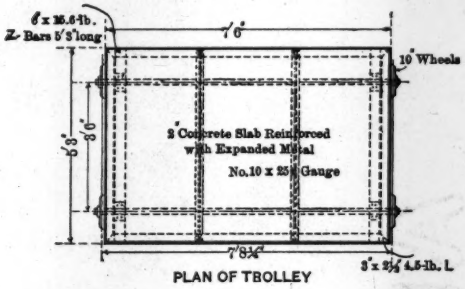
DETRITUS AND LIQUEFYING
DETAILS OF
SCREENING APPARA



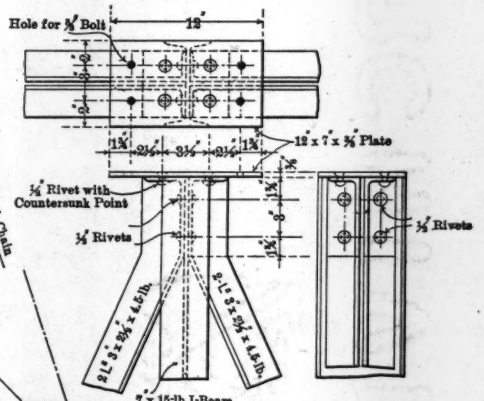


DETAIL AT *A*

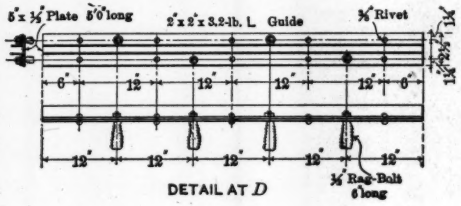




PLAN OF TROLLEY

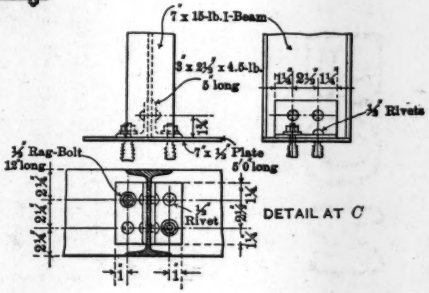


DETAIL AT *B*



DETAIL AT *D*

SEWAGE DISPOSAL WORKS
AT
SAN NICOLAS DE LOS GARZAS
DETRITUS AND LIQUEFYING TANKS
DETAILS OF
SCREENING APPARATUS



DETAIL AT *C*

diameter, controlled from valves with spindles carried above the coping level. Each of these pipes is connected to a central chamber, and leads to a 56-cm. (22-in.) sludge-pipe. The chambers as designed are of smaller capacity than those usually provided, but, as all surface water is strictly excluded from the sewerage system, the quantity of detritus reaching the chambers may be small. The velocity through them when both are in use will be approximately 0.082 m. (0.27 ft.) per sec.

From these chambers the sewage is carried to the three liquefying tanks by a main channel, 11.5 m. long and 1.50 m. wide.

The tanks are of concrete and have reinforced concrete roofs. Each is 66 m. long and 6 m. wide; the minimum depth for the sewage is 1.50 m. at the outlet end, and 2.25 m. at the inlet, increasing to a maximum depth of 2.75 m. at the lowest depth at the scour-out channel. Their combined capacity is 2 500 000 liters, which is equivalent to 6 hours' flow of the quantity of sewage for which they were designed. The sewage passes from the main channel, through penstock-valves which control the flow, into one or the other of the tanks. From these valve openings it flows over concrete weirs, 5 m. long, and is deflected to the bottom of the tank by a reinforced concrete scum-plate, extending across each tank, with a clearance of 15 cm. at each end. This scum-plate is 1.5 m. deep and 10 cm. thick, and is placed 40 cm. from the end walls.

The details of the concrete division and outside walls are shown on Plate XXIX. The floor was constructed in two layers, and its surface is divided into 6 channels formed by small walls, 20 cm. wide and 15 cm. deep, the object of these channels being to facilitate the cleaning of the floor by scouring it out to a specially arranged channel at the deepest point of the tank, near the inlet end. Each scour-out channel has a 30-cm. (12-in.) gate-valve, controlled from the roof of the tank, the three scour-pipes meeting in a concrete chamber outside of the tanks, from which a 56-cm. (22-in.) concrete pipe discharges the contents of the tanks to the sludge-pit during cleaning operations. The velocity through the tanks, when they are used in combination, is 0.0253 m. (0.083 ft.) per sec., the tanks being made as long as economically possible, in order to obtain this low velocity and thus permit the proper sedimentation of the suspended matters. The roof of each tank is 1 m. above the weir level. Each tank has four ventilating columns, 3.7 m. high and 30 cm. in diameter, vitrified clay pipes, with an ex-

terior casing of concrete, being used for the shafts. The roof is enclosed within parapet walls, and is covered with a layer of earth 25 cm. thick.

The outlet channel from the tanks leads to a measuring chamber, 3 m. square, as shown on Plate XXIX. This chamber is fitted with penstocks, 1.83 m. wide, and measuring weirs. From this chamber the sewage is delivered to two main irrigation ditches, which distribute the sewage in two directions, one northward and the other to the western extremity of the lands.

Construction of Tanks.—The excavation for the tanks was in soft earth for a depth of 1½ m.; the lower depths were in a firm foundation of sillar and calcareous clay. The total excavation in the tanks, channels, etc., was 8 335 cu. m., and the actual cost was 45¾ cents per cu. m. To facilitate the construction, about six-tenths of the concrete beams were cast as single monoliths and placed in position by sliding them across the tanks on temporary timbers. The remainder of the beams, the roof, and the slab were placed in position in the ordinary way with timber forms. The total quantity of concrete placed was 1 360 cu. m. A 1:2½:4½ concrete was used for the walls, channels, etc., and a 1:2:3 mixture for the roof slab and beams.

Table 14 gives the average cost per cubic meter for all the concrete work.

TABLE 14.—AVERAGE COST PER CUBIC METER FOR CONCRETE IN TANKS.

	Pesos per cubic meter.	Pesos per cubic meter.
LABOR:		
Mixing and placing	5.20	
Carpenter work in forms, framing, etc.	4.20	
Total labor cost		9.40
MATERIALS:		
Screened gravel	4.04	
Sand (from neighboring arroyo)	4.98	
Cement (including hauling)	15.19	
Lumber, nails, and other supplies	1.90	26.11
Total cost of concrete per cubic meter		35.51

Sludge-pit.—The sludge-pit, used when cleaning out the tanks, is carried 639 m. northward, far enough to get the available fall to drain the bottom of the detritus chambers and liquefying tanks. The drain-

FIG. 1.—FLUSH-TANK CARRIED DOWN BY FLOOD OF AUGUST 27TH-28TH, 1909.

FIG. 2.—VIEW SHOWING SCOURING EFFECT OF FLOOD ON SAN GERONIMO AQUEDUCT.

age pipe was formed of 56-cm. (22-in.) concrete tubes. The sludge-pit is merely an excavation in the earth 20 m. square and 2 m. deep, the sides having a slope of 1½ to 1. An overflow drains the pit to an irrigation ditch, the solid matter being allowed to settle and the liquid to drain off. From time to time it is proposed to dig out the solids and plow them into the land.

General.—To the east of the tanks a 3-roomed house has been built for the inspector.

In order to provide a good supply of water for cleaning operations, a well 22 m. deep has been sunk and is fitted with pumps operated by an Eclipse windmill, 4 m. in diameter, on a tower 22 m. high, which delivers the pump water to a circular wooden tank of 20 000 liters capacity.

The work in connection with the purification tanks was carried out by the Company's own staff; it was begun on September 10th, 1908, and practically completed by the first week in January, 1909.

At the time of writing, the tanks have to deal with the sewage from a population of only 10 000 persons, as only from 15 to 20% of the connections have been made. The sewage, therefore, has been diluted with several times its volume of surplus water, and the necessary scum on the top of the sewage in the tanks has not yet assumed the usual thick matty condition observed in most systems. As there are no available means in Monterrey of having proper determinations made of the degree of purification which takes place in the passage of the sewage through the liquefying tanks, a few simple tests have been made. These tests were limited to the determination of the amount of oxygen absorbed in 4 hours, and show a purification of 50% in passing from the detritus chambers to the outlet. The sewage, although very black and full of suspended matter as it enters the tanks, leaves them in a very clarified condition.

Of the total area of land acquired by the Company, 904 hectares (2 234 acres) have been leased to the Monterrey Railway, Light, and Power Company, for 99 years, the Water-Works Company reserving 5 hectares (12 acres) absolutely for future extensions of the sewage works. By giving 12 months' notice, the Company also reserves the right to utilize any part of 145 hectares (358 acres) near the tanks, should it be required at any time in the future for sewage purification purposes.

Quality of and Rates for Labor.

All the work was practically under the direction of English-speaking superintendents and general foremen. For the ordinary skilled and low-skilled labor, Mexicans were employed exclusively, and, on the work, which was quite new to them, they proved entirely efficient and satisfactory; throughout the work, on which at some periods between 2 000 and 3 000 men were employed, chiefly under the Company's direct administration, they were very tractable and willing to do their best, and no trouble was experienced at any time. The Mexican "peon," and also the ordinary skilled workman in the north of Mexico, is intelligent, and is excellent for purely routine work, but he is not adaptable or resourceful in cases of emergency. Under intelligent and careful supervision, however, it is quite possible to get as good results as could be obtained anywhere.

The daily rates of wages for a 10-hour day were approximately as given in Table 15, these rates being varied in special cases.

TABLE 15.—Rates of Wages.

	Pesos per day.
General foreman	8.00 to 10.00
Foreman	6.00 " 8.00
Cabos	2.00 " 4.00
Masons	3.00 " 4.00
Bricklayers	3.00 " 4.00
Masons and bricklayers, helpers	1.50
Cast-iron pipe jointers (foreman)	4.50
" " caulkers	3.00
" " helpers	1.50 to 2.00
Fire-clay pipe layers	1.75
" " helpers	1.25 to 1.50
Drillers	1.25 " 1.50
Carpenters	2.00 " 2.50
Blacksmiths	2.50
Crane men	6.00
Peons (laborers)	1.00 to 1.25
Boys (watering concrete)	0.37½ " 0.50
Watchman	1.00
Timekeepers	22.00 per week.

Cost of Works.

Table 16 gives the main items of the approximate expenditure. These include all expenses for preliminary location, engineering, superintendence, purchase of lands, water rights, etc., but do not include other heavy expenditures chargeable to the concession, such, for example, as general expenses, interest at the rate of 6% during the con-

FIG. 1.—VIEW OF SANTA CATARINA RIVER AFTER THE FLOOD.

FIG. 2.—VIEW OF SANTA CATARINA RIVER FLOWING THROUGH LOW-LYING STREETS, 8 DAYS AFTER THE FLOOD.

struction period, preliminary expenses for investigations, etc., items which would increase the total by nearly 25 per cent.

TABLE 16.—PRINCIPAL ITEMS OF EXPENDITURE.

	Pesos, Mexican currency.	
ESTANZUELA SUPPLY:		
Aqueduct and dam	502 000	
South Reservoir	429 000	
		931 000
SAN GERONIMO GRAVITY SUPPLY:		
Aqueduct, tunnel, and infiltration gallery	223 000	
Obispado Reservoir	436 000	
		659 000
SAN GERONIMO PROVISIONAL SUPPLY, including boring operations, etc		130 000
CITY WATER DISTRIBUTION SYSTEM		1 195 700
CITY SEWER SYSTEM		1 036 000
OUTFALL:		
Main outfall sewer	425 000	
Sewage purification works	75 000	500 000
Total		4 451 700

As a general statement, the actual cost of labor is about 33⅓% of the total cost of the construction work, including materials. Fig. 20 shows in graphic form the amount of the labor pay-rolls and the progress of the work during the whole construction period from 1906 to 1909, inclusive, comprising also that done under contract.

TARIFFS AND SANITARY REGULATIONS.

Tariffs.—The tariffs charged for the water and drainage service (Table 17) were approved by the State Government (which accepts the responsibility for their collection), under a compulsory State law which came into force on March 1st, 1910, for the southern portion of the city, and on July 1st, for the northern half, the penalty for non-compliance being a tax of 10% on the monthly rental value of the property, as assessed by the State officials.

The basis of the tariffs (which were published on February 22d, 1909) is a charge for water varying between 12 and 16 cents (Mexican) per 1 000 liters, with a minimum monthly rate for each different class of property connected to the system. The rate for house drainage is fixed at 80% of the minimum water rate levied on the consumer. The minimum rates have been fixed so that the poorer classes of the com-

munity will not be overtaxed, while at the same time the rate is actually levied on the quantity of water used, as indicated by the meter. All the services at the present time are metered, and the meter system will be used throughout.

TABLE 17.—THE TARIFFS.

Class.	Monthly property rental. Pesos.	Liters of water allowed.	Price for 1 000 liters. Cents.	Minimum monthly rate. Pesos.	Rate for drainage service. Pesos.	Total rate payable. Pesos.
I.....	Up to 20	7 800	16	1.25	1.00	2.25
II.....	21 to 40	12 500	16	2.00	1.60	3.60
III.....	41 to 60	18 750	16	3.00	2.40	5.40
IV.....	61 to 120	23 350	15	3.50	2.80	6.30
V.....	121 to 300	30 000	15	4.50	3.60	8.10
VI.....	301 upward.	33 350	15	5.00	4.00	9.00

"Notes: (1st) The rental for the water meters $\frac{5}{8}$-in. size ($15\frac{1}{2}$ mm.), which shall always be considered the property of the Company, will be 20 cents per month. Houses of the first and second classes shall be exempt from paying such rental for one year's time, counting from this date.

"(2d) All excess consumption of water over that allowed by the tariff will be charged for at 2 cents less than the price shown in the tariff per thousand liters.

"(3d) Extra large houses, large establishments, such as colleges, hotels, etc., etc., having a consumption of 50 000 to 60 000 liters of water per month, will pay at the rate of 14 cents per thousand liters. The drainage rate for such buildings will be arranged in proportion to the water tariff, or 80% of the value of the water.

"(4th) The laundry establishments, bath-houses, etc., when using 50 000 liters or upward, can arrive at some agreement so as to pay 12 cents per 1 000 liters.

"(5th) Groups can be formed of two or more small houses so as to obtain a joint service under the proportion shown in the tariff.

"(6th) Any other combination that cannot be entered into under the basis of this tariff, will be arranged by specially agreed upon prices, such agreement being as much as possible subject to the basis mentioned."

Sanitary Regulations.—The State Government, on March 1st, 1909, published regulations for the proper installation of the water and drainage services within the houses.

At the Government's request, a draft of the proposed regulations was submitted by the writer, who prepared it, after a study of American

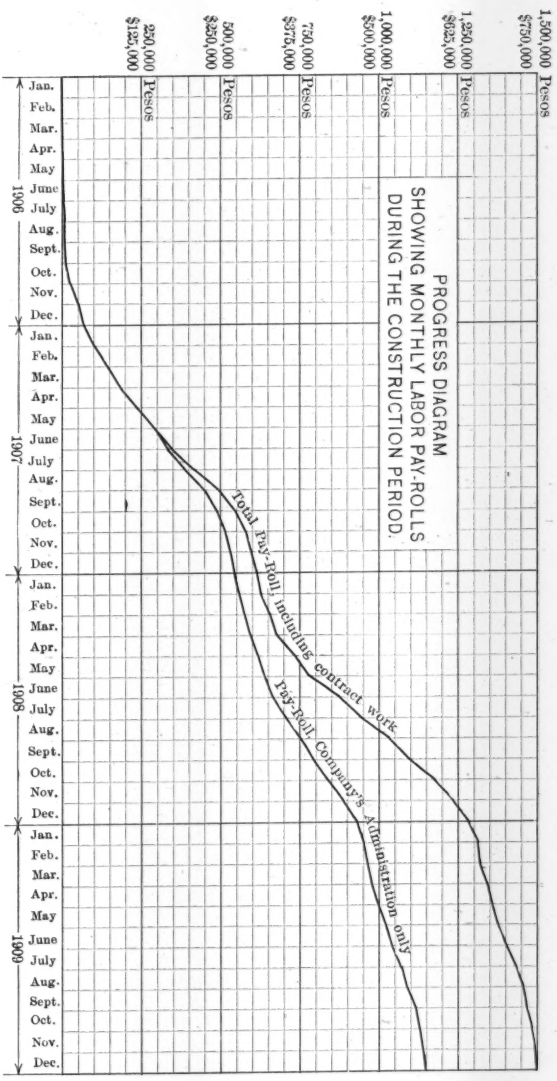

PROGRESS DIAGRAM
SHOWING MONTHLY LABOR PAY-ROLLS
DURING THE CONSTRUCTION PERIOD.
Total Pay-Roll, including contract work.
Pay-Roll Company's Administration only.
1,500,000 Pesos
$750,000
1,250,000 Pesos
$625,000
1,000,000 Pesos
$500,000
750,000 Pesos
$375,000
500,000 Pesos
$250,000
250,000 Pesos
$125,000
1906
1907
1908
1909
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

FIG. 20.

and British sanitary by-laws, to suit the special conditions of Monterrey. These regulations were afterward modified by him in collaboration with the Government Technical Inspector and Financial Interventor, and, in their final form, though not as stringent as those adopted in many northern cities, are probably more complete than those in any other Mexican city. Under these regulations only registered plumbers can undertake plumbing installations, and they have to execute a bond to the satisfaction of the *Alcalde Primero* (City Mayor) for the sum of 2 000 pesos as a guaranty of responsibility. For defective workmanship or any infraction of the plumbing regulations, they are liable to heavy fines, and can be called on to make good all defects in workmanship, without extra charge to the owner of the property. The provisions of the regulations are carried out under the supervision of the Government Technical Inspector, the Company's obligations extending only to the sidewalk and to the meters placed within the houses.

Engineers, etc.

G. S. Binckley, M. Am. Soc. C. E., was Chief Engineer of the Company from February to December, 1906. The writer was Chief Engineer from May 1st, 1907, until April, 1910, and is responsible for the design and construction of the works carried out during that period. Mr. J. D. Schuyler advised the Company throughout all preliminary studies and investigations, and acted as Consulting Engineer until February, 1908. The Technical Inspector, on behalf of the Government, throughout the whole progress of the works, has been Rudolf Meyer, M. Am. Soc. C. E., and the writer wishes to record the valuable assistance the Company has received from him.

In conclusion the writer may be permitted to pay a tribute to the devoted public spirit shown by his Excellency, General Bernardo Reyes, the Governor of the State of Nuevo León from 1885 to February, 1910, and who, untiring in his devotion to the interests of the city, was primarily responsible for the inception of the works and their successful completion.

DISCUSSION

JAMES D. SCHUYLER, M. AM. SOC. C. E. (by letter).—For completeness of detail and wide range of subjects of general interest to engineers, this paper is certainly one of the notable contributions to recent engineering literature. It is a minute and painstaking record of the successful accomplishment of construction work under unusual climatic conditions and difficult circumstances, and reflects credit on the author, not only in his capacity as an engineer, but as a faithful recorder of facts. It was particularly fortunate that he was an eye-witness of the disastrous and extraordinary flood which swept through Monterrey, destroying many lives and much property, and has thus been able to give an intelligent estimate of the maximum discharge of the river during the height of the flood wave of August 27th-28th, 1909, when the rate of run-off per unit of area of water-shed drained reached an amount which has seldom been equalled or exceeded, as far as reliable records extend. It is worthy of note that works deriving their water supply from the source of such torrential floods should have survived with so little actual damage, and with scarcely any interruption of service. The repair of all damages to the system was estimated to have cost not more than $20 000. Mr. Schuyler.

As Mr. Conway did not assume charge of construction until May, 1907, he was spared the responsibility of deciding on the general plan of securing an abundant supply of pure water from sources permitting of delivery by gravity under adequate pressure for fire protection—a responsibility which devolved on the writer, assisted by G. S. Binckley, M. Am. Soc. C. E., Mr. Conway's predecessor, as Chief Engineer. Not only the water-works, but the system of sewerage and sewage disposal by broad irrigation were subsequently carried out on the plans submitted to the State Government by the writer in 1906, and given provisional acquiescence at that time.

There was no lack of water at hand for the supply of a city of that size, as there are large perennial springs which flow out of the travertine of the plain, and are used for irrigation in the valley below the city. One of the largest of these, near the civic center, has a normal flow of nearly 30 cu. ft. per sec.; another nearby, also within the city limits, flows some 10 or 12 sec-ft., while both the Estanscia and Robalar springs, but a few miles below (shown on Plate II), discharge more than 20 sec-ft., as nearly as memory serves. Besides this supply, the water to be developed by sinking shafts in certain parts of the plain, as demonstrated at the brewery and elsewhere, was apparently a reliable source of large volume.

To utilize these sources, however, would have involved condemnation of the water-rights in the case of the springs, depriving present owners of the use of the water, and this Governor Reyes wished to

Mr. Schuyler.

avoid. Besides, it would have necessitated pumping the water for the city in perpetuity, an expense which the Governor was equally anxious to save; hence a gravity supply was made the prime requisite of the plans.

Until the concession was granted, and for a year or more afterward, it was assumed that an adequate supply could only be obtained by the storage of the flood-water of the Santa Catarina River in a large reservoir; and the earlier plans of the concessionaires were based on the construction of a high masonry storage dam at the upper end of the "narrows," where the river turns from a western direction to a course almost due east, between high vertical cliffs of limestone. The concession distinctly provided for such a dam, and among the plans on file in the State Capitol is one prepared by the late E. Sherman Gould, M. Am. Soc. C. E., for a masonry weir across the gorge. Samuel M. Gray, M. Am. Soc. C. E., also filed a plan and report proposing a capacious, shallow, storage reservoir near the city, to be filled by a large flood-water canal from the Santa Catarina Cañon.

Although the writer could not have anticipated the occurrence of floods of the magnitude of the one of August, 1909, which would surely have destroyed any reservoir built in the Cañon, he was unable to endorse the storage plan of water development, chiefly because of the uncertainty of the water-tightness of the reservoir in a cavernous limestone formation, and also because of the probable impurity of water draining from such extensive goat pastures. He, therefore, urged the development of the underflow of the river, which was manifesting itself in the springs referred to. Mr. Binckley secured two Keystone drilling machines and proceeded to profile the bed-rock at Santa Catarina Cañon and at San Geronimo, the two places on the stream where the river flows between walls of rock *in situ*. At both sites the strata were standing nearly vertical across the channel, and, by careful sampling and testing, it was found that in both locations there were thick strata of limestone so highly silicious as to be insoluble, and hence free from caverns. From this determination it was concluded that all the water which appeared in the valley below must pass through the sections where the borings were made. The results of this drilling, however, proved conclusively that the depth to bed-rock at either place was too great to permit of a masonry dam being considered as practical, and demonstrated the inadequacy of methods which had been used in the earlier investigations when dams were regarded as feasible.

The results have also shown that the subterranean supply at the lower cross-section of the river, at San Geronimo, is abundant, and can probably be increased to an indefinite degree by continuing the filtration gallery; while at Santa Catarina the same type of development can be made for a high-source supply, although requiring a long and expensive tunnel and conduit.

DAVID T. PITKETHLY, ASSOC. M. AM. SOC. C. E. (by letter).— Having been engaged on the design of sewerage systems for some years, the writer finds this paper of peculiar interest, particularly the sewerage portion. There are some points in the design, however, which do not appear to be clear. Mr. Pitkethly.

The system is described as "strictly separate," and yet the sewers are designed to run half-full, providing a capacity of 200%, the 100% basis, or 380 liters per capita, being 90%, or 180 liters, in excess of the calculated water supply of 200 liters per capita.

It has been the writer's practice to design sanitary sewer systems on the basis of the water consumption, and to assume the whole daily amount to reach the sewer in 16 hours, thus providing capacity sufficient to care for the maximum or wash-day flow without causing the sewers to run above the calculated hydraulic gradient, which should be placed within the pipe so as to provide air space for ventilation under all circumstances.

The practice of calculating sanitary sewers to run half-full is a good one when ground-water is expected in sufficient amount to fill the remaining portion of the sewer, but when no ground-water, or roof-, or surface-water is allowed to enter the system, or all precautions are taken to exclude such, then the system may be designed so that the expected maximum, or wash-day flow, will fill the sewer to the desired hydraulic gradient.

The method of ventilating the sewers does not seem practicable. The houses are principally of one story, and yet the stand-pipes on the sewers have openings 25 ft. 9 in. above the sidewalk. Are the ventilating or vent pipes of the house plumbing carried to a height to balance this, or will these chimneys draw the air from the house drains and fresh-air pipes, breaking the seal in the so-called disconnecting traps, thus causing the circulation of air in the house piping to be downward through the sewers instead of upward through the fresh-air inlets and vents, as designed?

It is interesting to note that crude sewage, as well as the liquefying (septic) tank effluent, is to be applied to land for irrigation purposes, but the application of crude sewage without any attempt at removing the suspended matter, or the effluent from the septic tanks where only a partial removal occurs, seems to be bad practice.

The author states that:

"The degree of purification in the tanks was relatively unimportant; the object to be obtained consisted chiefly in distributing on the land an effluent which would be innocuous and clear."

How he expects to obtain such an effluent by passage through screens, detritus tanks, and septic tanks only, is more than the writer can understand.

The removal of suspended matter in a septic tank depends on the

Mr. Pitkethly.

strength of the sewage, the time of retention, the time elapsing between cleaning, the presence of trade wastes, etc., and seldom exceeds 38 per cent.

The subject of septic tanks and their effect on sewage is discussed in the "Fifth Report of the Royal Commission on Sewage Disposal" (England, 1908), and the following extracts, relative to the application of crude sewage to land and the effect of septic tanks on sewage, seem apropos:

"23. * * * There are also many cases in which crude sewage has been passed over land, but the evidence shows that land treatment of crude sewage is liable to give rise to nuisance by the accumulation of solids on the surface of the land. Moreover, in some cases these solids are apt to form an impervious layer, which interferes with the aeration of the soil, and so impairs the efficiency of the treatment."

"31. * * * At that time it was claimed that the septic tank possessed the following, among other, advantages:

"That it solved the sludge difficulty, inasmuch as practically all the organic solid matter was digested in the tank.

"That it destroyed any pathogenic organisms which there might be in the sewage."

"32. As regards the first of these claims, it is now clearly established that, in practice, all the organic solids are not digested by septic tanks, and that the actual amount of digestion varies to some extent with the character of the sewage, the size of the tanks relative to the volume treated, and the frequency of cleansing.

"At Huddersfield, Mr. Campbell estimated that about 38 per cent. of the solids were converted into gas or digested; * * * while at Birmingham, Messrs. Watson and O'Shaughnessy say that the figures available indicated a digestion of not more than 10 per cent. of the suspended matter entering the tanks."

"33. As regards the second claim, we find as a result of a very large number of observations that the sewage issuing from the septic tanks is, bacteriologically, almost as impure as the sewage entering the tanks."

Messrs. Winslow and Phelps, in their interesting paper, "Investigations on the Purification of Boston Sewage,"* quote a suggestion made by Stoddart (1905):

"He finds, in a septic tank of several compartments, a considerable deposit of sludge in the first compartment, giving a fairly clear supernatant liquid, which in the last chamber of all undergoes a secondary decomposition, leading to the throwing down of an additional precipitate of offensive sludge."

What took place in the case referred to by Stoddart corresponds to the author's observations of the liquid leaving the tanks in a clarified condition, but the secondary decomposition must take place in some manner, and, when it does, a nuisance seems to be unavoidable where no provision is made to care for it.

* Water Supply and Irrigation Paper No. 185, p. 125.

In view of the experience of others, some further treatment seems to be necessary. Such treatment should include disinfection, as no method of disposal yet devised has succeeded in reducing materially the pathogenic germs usually to be found in sewage and tank effluents. Mr. Pitkethly.

If the crops to be irrigated are to be eaten, uncooked, by mankind, then disinfection at least is imperative.

GEORGE S. BINCKLEY, M. AM. SOC. C. E. (by letter).—Mr. Conway's admirable paper is of special interest to the writer, as the entire general design of the system, as well as the extensive hydrological studies and final selection of the sources of water supply, was completed during 1906 through the joint labors of the writer, as Chief Engineer, and James D. Schuyler, M. Am. Soc. C. E., as Consulting Engineer. Mr. Binckley.

In this work, Mr. Schuyler and the writer had the rare privilege of dealing from its inception with the problem of designing a complete and somewhat extensive system of municipal water supply and drainage, unhampered by any existing works to which the new systems would have to be adapted. It would probably be difficult to find in the United States a city of 85 000 inhabitants, previously totally lacking either a water supply or sewerage system, which, under a consistent and harmonious design, has been provided with both in the degree of completeness and structural excellence exemplified in the works at Monterrey.

The few important changes or amplifications made in the original design, and the manner in which its detail has been executed is naturally most interesting to the writer, and this excellent paper should be of very substantial value, particularly to engineers engaged on similar work in Mexico or Spanish America.

The very novel construction method adopted by Mr. Conway in the roofing of the South or Guadalupe Reservoir, seems to the writer rather to invite criticism, and the fact that in the subsequent construction of the roof over the rectangular Obispado Reservoir the customary monolithic concrete construction was apparently reverted to after experience with the separate-unit plan previously used, would indicate that Mr. Conway reached the same conclusion.

The original design of the circular Guadalupe Reservoir contemplated just about the same arrangement of columns and roof support as that actually used, but the writer had expected that the columns would be cast in place, and that the system of primary and secondary beams would be filled at the same time as, and integral with, the roof slab, the reinforcement being placed in accordance with what may be described as conventional practice. The writer believes that the efficiency of the concrete and steel placed in this manner would be notably higher than under the system actually adopted, which, in effect, is pretty much the same as constructing the supporting system of units of cut stone. If, with all the elements of structural weakness involved in the multiplicity of mortised joints, discontinuous rein-

Mr. Bluckley.

forcement, etc., this construction is strong enough, it would seem that an important reduction in the dimensions of the members could have been effected by monolithic construction and continuous reinforcement, without sacrifice of strength.

The comparison, in Table 7, of the costs of these two reservoirs, is interesting, but very moderately illuminating, as the comparative unit cost of the most important element in their construction—the concrete—is not given. The total excavation cost for each reservoir is practically the same, and the general expense, engineering, and cost of fittings and accessories presumably so, but the total cost of the Guadalupe Reservoir as given is $19 000 (pesos) in excess of that of the Obispado Reservoir, while, in the latter, there were 756 cu. m. more concrete. This certainly indicates a much higher cost of concrete per unit as laid in the South (Guadalupe) Reservoir. An actual comparison of the cost per unit of concrete laid under the two systems would be instructive.

The writer is interested to observe that the same system of subdrainage used by him in the construction of the reservoir for the provisional supply of water from San Geronimo, has been used by the author in the Obispado Reservoir. This arrangement of drains under the floor of the reservoir at San Geronimo was devised as a safeguard against damage to the lining through the accumulation of water inside the impervious bank against its back.

It was realized that, in such a climate as that of Monterrey, perfect water-tightness of the lining might be difficult to secure or maintain, and, if leaks existed, a sudden draft on the contents of the reservoir might result in serious damage through the static pressure exerted against the lining of the sides or upward thrust against the floor. In the writer's opinion, such a system of drains is an important element, as not alone the fact but the quantity of leakage may be determined, and danger of saturation of the supporting bank avoided—a matter of importance where, as is sometimes the case, the material of such a bank is unfit to resist the effects of saturation. The author does not state whether or not this safeguard was omitted in the Guadalupe Reservoir. Incidentally, however, the matter of saturation of the bank is not important in either reservoir, as the material of which these banks are constructed is such that settlement or failure through saturation is out of the question. It may be remarked, however, that in fixing the angle of the sides of the Guadalupe Reservoir at 60° the writer contemplated the same system of constructing the bank as he used in that of the San Geronimo Reservoir. In this case, the bank was built up by spreading the material in thin layers, wetting down, and rolling and puddling by the passage of the ox-carts used for the transportation of the material, the wheels of the carts, and especially the cloven hoofs of the animals, producing a most excellent effect. The inside slope

was built up in this fashion to a much lower angle, and with a top width considerably in excess of the finished dimensions. The excess material was then picked off to the line, and exactly to the slope. Thus the finished slope presented a surface which was compacted to a degree impossible to attain at or near the surface of the bank as built, and presenting a support of the best possible character for the concrete lining and coping. Mr. Binckley.

V. SAUCEDO, ASSOC. M. AM. SOC. C. E. (by letter).—The author's description of the water-works and sewerage of Monterrey, one of the most extensive schemes in Mexico, will be of general interest to engineers, especially those engaged in hydraulic and sanitary problems. The writer, having been connected with the works for four years, knows the local conditions well, and presents herewith some complementary data on what he considers an important feature, the subject of floods, mentioned by the author on different occasions, especially as certain developments in the works show the importance of such occurrences as a factor in designing. Mr. Saucedo.

Abnormal rainfalls of long duration and high intensity are common in the semi-arid region of Mexico. They come at irregular intervals, though tending to coincide with the early fall. The floods of August, 1909, were a repetition of similar occurrences in the past; and, though there are no numerical records of previous cases, local traditions and historical state documents describe them as having occurred since the foundation of the city, at intervals of from 15 to 40 years. The graphic descriptions of the places flooded are in accord with the character of the floods of August, 1909, and September, 1910.

The diagram, Fig. 21, is a record of the rainfall during the latter flood, and was plotted from intermittent readings of standard gauges. It demonstrates that the intensity increased toward the mountains on the south, which form the tributary water-shed of the Santa Catarina River, showing a difference of 10.54 in. between the city and the Estanzuela Dam, which is not quite 12 miles to the southeast.

An estimate of the volume of discharge of the river at the time of maximum flood is only a reasonable conjecture which (without special reference to accuracy) aims to impress those who have not witnessed such occurrences with the tremendous volume coming from barren steep surfaces previously saturated.

The original computation, referred to by the author, was obtained from the average of two different methods which gave results close to each other. In one method the extent and nature of the water-shed were considered, together with the maximum period of precipitation that occurred, sufficient to gather a maximum volume of water in the river. In the other method the volume was derived from a cross-section of the wetted perimeter of the river at the time of maximum flow, in combination with velocity approximations obtained by using

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rough floats. This gave 271 500 cu. ft. per sec. The figure submitted by the author, 235 000 cu. ft. per sec., is in accord with the proposed formula* for impervious surfaces by C. E. Gregory, M. Am. Soc. C. E. In the first and last methods, the intensity, a governing factor, is more or less of an assumption, and the cross-sectional method is also unreliable, as the river-bed was greatly disturbed, due to the high velocity of the water, which deepens the channel to a considerable extent at times of maximum flood, the gravels being redeposited during the

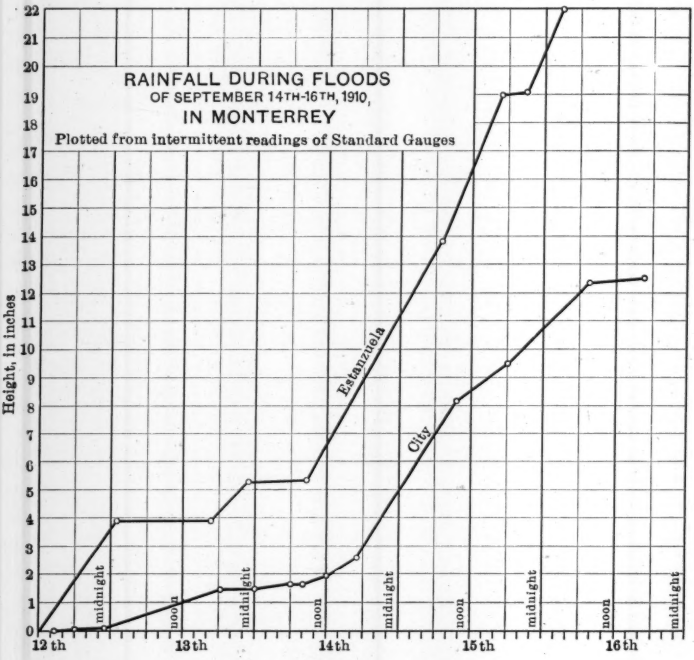

FIG. 21.

period of subsidence. Such was the case during the flood of September, 1910, when the depth of gravel above the roof of the San Geronimo Infiltration Gallery was diminished to such an extent that it was so inefficient as a filter for the flood as to permit the percolation of turbid water into the underground supply.

During the floods of August, 1909, Shafts Nos. 2 and 3 were damaged beyond repair, and sand and gravel, entering through them,

* *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 458.

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blocked up the gallery to within about 150 ft. of Shaft No. 1. The interior timbering probably collapsed, due to cavings and disturbance in the river-bed during the period of maximum flood, but no explorations have been possible on account of the great quantity of water still coming through (at present more than 650 liters per sec.). For this reason the work of driving the gallery, as well as lining Shaft No. 1, has been suspended.

On reaching the city, the flood of August, 1909, swept away two streets adjoining the river. These streets had been built on made ground, in what was originally the river-bed. The sewers and water mains laid in them were destroyed entirely, and some 460 ft. of the 24-in. cast-iron pipe, buried under the river-bed at a depth of 8 ft., were carried away. In relaying this portion of the main, and for protecting the remainder of it across the river, it is now proposed to encase it in a solid rubble concrete block, 8 ft. square, which will impart weight and stability against the scouring effect of floods.

The South Reservoir is circular in shape, with an interior diameter of 165.68 ft. at the top, and is partly excavated in the ground and partly completed by an embankment of vast proportions (Fig. 10). Right after the flood of August, 1909, a wet spot appeared on the northeastern toe of the embankment, and it was supposed for some time that it was the effect of the saturation produced by the preceding rains, but, as it persisted for several months, it was obvious that its origin was in the interior of the reservoir, which was emptied when the writer took charge of the work. The first inspection revealed a horizontal crack in the concrete lining, about 310 ft. long and extending about 153° around the circumference on the north side. Throughout its length it coincided with the line of cut and fill. Vertical cracks, coinciding with the panel points in the lining, had also developed, and extended from the main horizontal crack to the roof. The circumstances originating this development can be conjectured by considering the position of the main crack, its characteristic features, and the conditions that preceded its formation. The coincidence of the crack with the joint of cut and fill, points to this line as a source of danger. An examination showed, besides, that the fracture was clean and sharp, ranging in thickness from a hair line at the ends to $\frac{3}{16}$ in. at the center, and that its upper border projected over the lower one perceptibly, a proof that horizontal motion had taken place. The vertical cracks were a secondary effect, the consequence of the displacement immediately after it was scoured. A fracture was discovered in the floor of the reservoir. It started at the center and branched out into two diverging lines in a radial direction.

The circumstance of two abnormal rainfalls, giving 35 in. in 9 days, the precipitation being concentrated in two periods, not far

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apart, of 42 hours and 98 hours, respectively (Fig. 5), together with lack of provision for shedding the water from the roof of the reservoir and from the surrounding embankment, lead to the inference that the latter became saturated, increasing thereby in weight and decreasing in stability, especially in its steep inner face. A settlement and the consequent horizontal displacement, under these conditions, was natural. The concrete lining, only 16 in. thick at that height, was not sufficient to sustain the resulting strain, and the main fracture developed, permitting the stored-up water to leak into the bank. In time this seepage found its way under the bottom of the reservoir, softening the ground and producing a slight settlement which caused the crack in the floor. Had under-drainage been provided, as at the Obispado Reservoir, the actual conditions would have been noticed earlier. However, as the embankment is of vast proportions, stable in itself to sustain with a large margin of safety the weight of the stored-up water, there was no actual danger of failure, except for the fact that the material forming the structure, on account of its calcareous nature, is dissolved by water. Long exposure to this condition would, in time, open passages in the embankment, and it is certain that there would be cavings in its interior.

The necessary grouting has been done, and provision is being made for water-proofing the interior of the reservoir and shedding the water from the roof and from the embankment, thus relieving the structure of the consequent strain.

Another place in the works where floods have had a damaging effect is the Estanzuela intake basin, which, when the dam was completed, was filled to the overflow level in order to test its water-tightness. As this basin, when cleaned, was found to be slightly fissured on the north side, it was decided to line it with concrete. As shown in Fig. 8, the lining does not cover its entire area, but only the central portion, leaving a strip on either side without protection. The flood of September, 1910, coming in greater volume than the previous ones of August, 1909, in passing through the narrow gorge at the entrance, undermined the lining in those places where it was not founded on solid rock. Figs. 1, 2, and 3, Plate XXXIII, show some of the damage caused by this flood. The buoyant effect of the water and the impact of large rolling boulders caused fractures all over the surface, and lifted the concrete lining bodily; but the dam proper, being founded on rock bottom, did not suffer any injury. In the future, in order to avoid the seepage of the ordinary supply, alluded to by the author, the water will be carried to the valve-house in an open rubble concrete channel, lined with cement mortar and built high up against the western hillside. The remainder of the basin will be paved with large boulders.

In conclusion, the writer wishes to emphasize the point that, not-

FIG. 1.—ESTANZUELA DAM: BROKEN CONCRETE BASIN LINING.

FIG. 2.—ESTANZUELA DAM: BROKEN CONCRETE BASIN LINING, EAST SIDE.

FIG. 3.—ESTANZUELA DAM: FRACTURES OF WALL AND LINING.

withstanding the severity of the test, relatively small damage was inflicted on the extensive works carried out under the author's design and direction. A test so severe that it caused serious damage and immense losses in the entire region, washing away kilometers of railroad track and destroying practically all the bridges within reach of the flood, is an occurrence of paramount importance, and should be remembered as a leading factor in the design of engineering works. Mr. Saucedo.

GEORGE T. HAMMOND, M. AM. SOC. C. E. (by letter).—In a country, such as that described in this paper, where water is valuable, and a shortage is at times possible, where the majority of the population is very poor, and water and sewage discharge are both to be paid for on a basis of volume, the question of the expected quantity of daily water supply and sewage flow per capita is of primary importance. This question, notwithstanding its difficulty, should be given a first place in the studies for water-works and sewerage projects, and should never be lost sight of in the design, which should be such that, while proper for the expected future flow for a reasonable time, should also be proper and economical for conditions which at present obtain and may change but slowly. Mr. Hammond.

It is desirable, of course, to get as much capacity in works as one can for the outlay, but there are instances where one can get too much for the money, as where a larger pipe than is necessary is used for a sewer, merely because it costs about the same as a smaller one, and as a result the cost of maintenance is permanently increased.

The water-works were designed to supply 40 000 000 liters (10 582-000 gal.) daily, which it was assumed would be sufficient for all future developments in Monterrey for a population of 200 000 at a per capita consumption of 200 liters (about 53 gal.) per day. The present population of the city is given as less than 90 000, there having been an increase of 22 000 in ten years (1891-1901), but it is evident that in the last ten years (1901-1911) this rate of increase has not continued. Taking into account all the data known to the writer, it does not seem that the city will attain a population of 200 000 in a great many years, if it ever does; but this is a matter of personal opinion, and is only stated as such.

The present requirements of the city's population, assuming that each person uses 200 liters (53 gal.) per day, would be, at that rate, which is a very liberal one, only 18 000 000 liters (4 762 000 gal.) per day, or less than half the amount which may be provided.

If the water were not to be metered and the sewage discharge paid for by measure, it is possible that the free use of water might lead to the usual waste with which all are fairly familiar; but the use of meters, and the rates charged, will reduce the water consump-

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tion to a minimum. This end will especially result from Section 5 of the Tariffs which provides that:

"Groups can be formed of two or more small houses so as to obtain a joint service under the proportion shown in the tariff."

This provision will keep down the per capita supply, among the majority of the people, to about 37½ liters (10 gal.) per day. A similar provision led to abuse in Santiago de Cuba, as well as in other Cuban cities, where one householder, taking water, frequently delivers it to adjoining houses and tenements through rubber hose. As many as ten or twelve families are sometimes found to be supplied from one tap in this manner. Indeed, it may be stated as a rule, having but few exceptions, that where water is paid for by meter its use is always restricted.

The water mains and distribution system, however, are so well laid out, and the whole design is so good, that the writer would not anticipate much difficulty because it is on rather too liberal lines for the present or probable future. It may, perhaps, be argued that it may cost more to keep the mains in such a system clean; but this extra cost will scarcely be of much moment, and will be offset by the greater lasting quality of the larger pipes. There is another feature of the problem, however, which is not affected favorably by a too liberal forecast of the per capita water supply, namely, the sewerage system.

If it is assumed that, using 200 liters per capita per day, the total water supply of the city for the present population will be 18 000 000 liters, and that this may double in fifty years, or even amount to 40 000 000 liters in that time, it would seem that a rather liberal provision has been made for the water supply, and that this will scarcely be exceeded by the sewage, for the latter must come from the water supply, there being little or no ground-water and no storm-water taken into the sewers. Designing the sewers to flow half full for all diameters less than 18 in., and seven-tenths full for all larger sizes, it would seem that this would give ample capacity for all time to come in such a city, and that good practice would not exceed these figures, it being more desirable that the sewers should not be too large to work well, than that they should be large enough in all places to meet every possible contingency. If all the sewers of a system are too large, the condition is incurably bad; while, if a few miles prove to be too small, on account of growth and prosperity not anticipated by the designer, it will be easy enough to relay such parts when this becomes necessary.

Mr. Conway states that:

"The sewers are designed on a very liberal basis, namely, on the assumption that when flowing half full the quantity to be dealt with will be 380 liters [100 gal.] per capita per day, with a maximum rate of flow of 200 per cent."

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If the writer understands this statement correctly, it means that the sewers, flowing half full, will carry 380 liters per capita in 12 hours, or are designed with 200% of the capacity required to take the assumed flow in 24 hours.

It was assumed that each house would be occupied by 7 persons and have a frontage of 12½ m. (about 41 ft.), that is, about 700 gal. per day per house, the maximum flow rate being 200%, or at the rate of 700 gal. per house in 12 hours.

It is to be remembered that nearly all the houses are of one story, and that, as a rule in tropical and sub-tropical countries, the per capita use of water diminishes with some function of the increasing number of inhabitants in one house. Most of the water is used in the kitchen, and where there are 7 persons instead of 5, the quantity used by the smaller number will generally serve the larger.

The writer is unable to understand how this quantity of sewage will be produced, especially as the author states that, as far as the company is concerned, it is limited to the removal and disposal of the sewage, and is not required to provide for storm-water. He also states that:

"Apart from that fact, however, the best system for a city like Monterrey, where rainfall for many months at a time is very scarce, is the strictly 'separate system'."

The minimum velocities in the sewers, when running full, vary between 0.91 and 1.5 m. (from 3 to 5 ft.) per sec., and will be the same flowing half full.

From the foregoing data it will be observed that:

(1) The water supply is the only source from which sewage flow is anticipated;
(2) The water supply is very liberally estimated at 200 liters (53 gal.) per capita daily;
(3) For purposes of sewer design, the daily flow of sewage expected (all of which is derived from the water supply of 200 liters per capita) is estimated at 380 liters per capita, with a maximum rate of flow of 200% (or at the rate of 760 liters per capita), and with this quantity the sewers are designed to flow only half full;
(4) The gradients are such that a velocity of from 3 to 5 ft. (0.91 to 1.5 m.) per sec. will be secured in the sewers flowing half full with the above quantity of flow per capita.

The writer does not agree with this method of computation, as he feels sure that it will give sewers which are too large, with grades too steep for the best obtainable results. His experience, extending over more than twenty years in sewer design and hydraulic work, convinces him that the method pursued is wrong in principle.

The principles involved in sewer design are first of all hydraulic. The quantity of flow, in the nature of things, cannot be forecasted

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accurately; success depends on getting the nearest possible approximation to average conditions. If 200 liters per capita per day is a liberal allowance, and 40 000 000 liters per day is a liberal expectation at this rate for double the present population, and the sewers are designed to flow half full only, why should this again be doubled?

The design of a sewer system for a city such as Monterrey is, in fact, a very difficult problem, especially as the quantity of sewage will be very limited, flush-water will have to be used in considerable quantities, and water in that part of the world is precious at all times and often scarce. Under these circumstances, the size or shape of the pipes selected for the lateral sewers, should have been such as would more nearly agree with the requirements than does the 8-in. circular.

A. P. Folwell, M. Am. Soc. C. E., writing of the 8-in. circular size, states:*

"To secure a flow in this pipe having an average depth of 4 inches would require the sewage from a population of 6 500. In general it may be said that the ordinary depth of flow in any sewer should not be less than 2 inches, nor should it be less than ½ the radius of the invert, since if it is so there is much more danger of deposits forming along the edges and even in the center of the stream. It will sometimes be impossible to meet this requirement fully, but it should be kept in mind as extremely desirable."

Sewers of small size should be proportioned throughout the system so that the depth of the minimum daily flow in the invert, and the velocity of flow, will be the best possible to prevent deposits. The transporting power of water is dependent mainly on the depth of flow, a minimum velocity being selected rather than a minimum depth of flow. To those who have had charge of the maintenance of sewers, as well as of their design and construction, this principle seems so obvious that it is always a surprise to see it disregarded by designers, who in these days seem inclined to consider sewerage as a system of grades and sizes of pipes installed for ideal, rather than for actual, conditions. Messrs. Staley and Pierson have well stated the principle involved as follows:

"A stream having a depth of flow sufficient to immerse solid matter held in suspension, to a certain extent lifts it and carries it forward. The entire surface is also exposed to the action of the current. A stream having an equal velocity but a less depth in proportion to the diameter of the solid matters to be transported, evidently has less transporting power. * * * An amount of sewage which can be properly transported by a circular sewer of a given size, cannot be as efficiently transported by one of larger diameter."

From some strange idea, which is apparently without foundation in logic or based on any actual justification from experience, it has of late years become the practice of designing engineers to make the

* "Sewerage," by A. P. Folwell, M. Am. Soc. C. E.

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8-in. circular pipe the smallest size for sewers; and it is not improbable that the designer of the Monterrey system has merely followed this example. It has also become the frequent practice of designers to give every length of sewer all the grade possible, regardless of the fact, taught both by hydraulics and experience, that the best grade is that which will give as much depth of flow as is consistent with a scouring velocity.

Some years ago it was the standard practice, in the "strictly separate system" of sewers, to use the 6-in. pipe as the minimum size, and, as far as the writer has been able to discover, after giving the matter a rather extensive investigation, the 6-in. size has given excellent results wherever its use was proper. In places where it has not succeeded there were excellent reasons why it should not have been selected, and these could easily have been observed at the time the designs were made. The best sizes for the sewers in a given system is always a matter to be determined by local conditions; but there seems to be no reason why the 6-in. size should not be used where the flow is so slight that the 8-in. will not work well; or where the velocity must of necessity be so great that a flotation depth of flow cannot be maintained in the larger size. As to likelihood of clogging and stoppage, the writer's opinion, based on the maintenance of three rather extensive systems in different parts of the United States, in each of which the 6-in. size comprises more than 75% of the whole length of pipe, and of three other systems, one having 12-in. and two having 8-in. as the minimum sizes, is that the 6-in. size, where properly used, is less likely to become clogged than either of the others used improperly. The cost of maintaining the 6-in. pipe lateral, under these circumstances, is much less than that of maintaining the 8-in. lateral.

The 6-in. pipe is not being used now as much as the 8-in., and in most cases this is probably because the capacity of the latter is nearly double that of the 6-in., and costs only a few cents more per foot. If there is a sufficient population per acre, or if, within 30 or 40 years, such a population is anticipated as will fill the 8-in. pipe half full, its use, of course, is justified and necessary; but where it is quite evident that this will never occur, its use is counter-indicated.

In Monterrey, where the building lots have a frontage of 41 ft., where the houses, as a rule, are only one story high, where the water service is metered and paid for, and the sewage flow is also paid for, there seems to be no reason to justify the use of 8-in. pipe for the upper reaches of the smallest sewers. The sewage flow to be anticipated will probably never be sufficient to keep an 8-in. pipe sewer in a good clean condition at the upper ends of the lines of sewers without excessive flushing; and the sharper or steeper the grade on which it is placed, the worse will be the result, because the sharper the

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grade, the thinner the flowing thread of sewage will be drawn out in the invert; on the other hand, if the grades are flat, the slight quantity of sewage flow will be spread out in a sluggish stream, without sufficient depth, on the bottom of the 8-in. pipe.

Where a wide surface is given to a small quantity of flowing sewage, it stagnates slowly along the bottom of the sewer, leaving frequent deposits to undergo decomposition and create foul air, if not to choke the sewer, a result often produced; and where a circular sewer which is too large for the ordinary flow is given a strong velocity by using steep grades, the stream, though flowing rapidly, is drawn out to such a thin thread that it will not effect the flotation of the solid masses in the sewage brought in at house connections, and the shallow and thin stream simply flows around such masses until a dam or obstruction forms and the sewage is backed up sufficiently to force the obstruction farther down, to form another obstruction in a larger pipe below. Flushing may possibly keep such a sewer fairly clean; but, as usually practiced, it is effective only for a few hundred feet from the flush-tank; and the quantity of flush-water required by an 8-in. pipe is more than twice as much as that required to keep the 6-in. pipe clean. Ventilation is better in the smaller sewer than in the larger, as there is less air to move; but the elaborate ventilating stacks provided at Monterrey may take care of this; and it is evidently a place where ventilation will be needed.

The ideal size and shape of cross-section for a sewer is such as will give the best flotation to moving solids which are being carried along by the flow; and this means the sewer that, with the expected ordinary or average flow, will give the best depth in the invert, when the velocity of flow is sufficient to keep suspended solids, grit, etc., moving at a rate of from 2 to 3 ft. per sec. The size, however, is limited by practical considerations. The circular pipes cannot well be less than 6 in. in diameter, because the house connections cannot well be less than 4-in. pipe, and the sewer should be larger than the house connections, for various practical reasons; but, in order to secure flotation and a scouring flow, the smallest pipe, or the pipe having the smallest invert radius, that practical considerations permit, should be selected. The grade should be such, and the collecting system so laid out, that the flow may be conserved as far as possible, and the sewage flow should be kept of as great a depth in the invert, or bottom of the sewer, as safety in self-cleansing velocity will permit. This will save flush-water and prevent stoppages, and thus reduce the cost of maintenance to a minimum. For good sanitary practice, the sewers should be designed, first of all, to comply with the requirements of the present, or immediately expected, ordinary flow, with some reasonable allowance for the future. They should be

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neither too large nor too small, and the grade should neither be too great nor too little, to secure the best flotation and scouring effects and the best flush-wave action under all circumstances.

The use of cement concrete pipe for sewers seems to be growing in favor; nor is this surprising, in view of the many improvements made in their design and manufacture. The excellence of the concrete pipe used in Monterrey and its success, suggest the query: Why was it not used still more extensively?

Table 13 shows that the cement pipe cost much less than the vitrified tile, or "fire-clay" pipe. Thus, the 38.1 cm. (15-in.) fire-clay cost 6.14 pesos per lin. m., the 45.7 cm. (18-in.) cost 8.80 pesos, and the 50.8 cm. (20-in.) cost 11.30 pesos. Compared with this, the concrete pipe was much the cheaper; the 55.9 cm. (22-in.) cost 5.93 pesos, which is less than the cost of the 38.1 cm. (15-in.) fire-clay; and the 61.0 cm. (25-in.) concrete pipe cost 7.30 pesos, which is less than the 45.7 cm. (18-in.) fire-clay.

The writer's experience with concrete pipe, derived mainly from a long service in sewer design and construction in Brooklyn, N. Y., leads him to believe that at Monterrey the whole sewer system might, with advantage, have been built of concrete pipe, using an egg-shaped pipe with an area slightly larger than an 8-in. circle, designed for a discharge equal to an 8-in. pipe for all the smaller sewers. The invert of such an egg-shaped pipe would fulfill the present requirements in carrying a very small flow with good flotation depth, better than would a 6-in. circular pipe, and the reserve capacity of the 8-in. pipe would be secured without interfering with good present service. Egg-shaped pipes, similar to those used in Brooklyn, the writer believes, would have given far better satisfaction throughout the Monterrey sewerage system than circular fire-clay pipe, and would have cost no more, but probably less. The egg-shaped pipe referred to is made with a flat base and a self-centering joint, thus insuring perfect alignment, and a smoother interior surface than can be obtained with fire-clay pipes.

Brooklyn has about 450 miles of concrete pipe sewers, of all sizes less than 24 in., the greater part of which is egg-shaped. There are also about 250 miles of vitrified stoneware circular pipe sewers of similar sizes, and the cost of repairs and replacing pipe, over a period of years is about the same per mile for each kind. Incidentally, it may be stated that the annual cost of repairs per mile on both kinds of pipe is very small, and is only about one-fifth of the cost of repairs per mile on the brick sewers, of which there are about 200 miles.

The principal advantages and disadvantages of cement concrete pipe sewers may be summed up as follows:

Mr. Hammond.

ADVANTAGES OF CONCRETE PIPE.

(*a*) Cement concrete pipe is usually less costly than vitrified pipe.

(*b*) It can be formed in any shape desired.

(*c*) It is not cracked by vibration, and resists impact better than vitrified pipe, for which reason it is a better material to lay near the surface of a street in which there is heavy traffic.

(*d*) It is not affected by ordinary sewage.

(*e*) The cost of repairing and maintaining is about the same as for a vitrified pipe sewer.

(*f*) It can be made in the city or town where it is to be installed, thus giving the locality the advantage of having some of the money paid for labor in its manufacture spent in the place where the sewers are being put in, where it is raised as a tax, etc.; also saving freight charges, etc.

(*g*) It can be made under the most careful local supervision and inspection, of selected material, by the engineer who is responsible for the success of the work. Vitrified pipe can seldom be made in this way.

DISADVANTAGES OF CONCRETE PIPE.

(*a*) If not carefully made and of the best of materials, it is subject to failure by disintegration, etc.

(*b*) It will not stand strong chemical action, and therefore the smaller sizes should not be used where they are likely to be exposed to trade wastes containing strong acids. In the larger sizes the quantity of flow mixes so quickly with the trade wastes that this danger is minimized, and it is very seldom that even the smaller sizes become affected; but vitrified pipe may be used in places where chemical action is anticipated.

(*c*) If not properly made, it will be attacked by steam and hot vapor, and by animal fats in the sewage; but, if properly made, it is not affected by these.

(*d*) Unless reinforced or made very thick, it will not stand as great a crushing load as the best vitrified stoneware pipe; but, as sewers are not intended to be used under very heavy pressure, this is not so very important. It is amply strong to withstand any internal pressure or any external crushing load to which it probably will be submitted.

(*e*) Under a considerable head of ground-water, it may permit water to infiltrate through its walls for a considerable time after it is laid, thereby temporarily increasing the flow, which, if the sewage is to be pumped, will increase the cost of pumping. This difficulty can be met by using a carefully selected mix of materials in making the pipe, and by making

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the joints carefully. Infiltration through concrete diminishes rapidly after the sewer is in use; it occurs in vitrified pipe, also, to some extent.

The house connection drain adopted in Monterrey, with the disconnecting trap, is very much like one which the writer has seen introduced with very bad result. These are being removed as rapidly as possible by one of his clients, a sewerage company, in the Southern States. It has been a fruitful cause of stoppages and bad smells; the ordinary method now in general use is much better. In the design shown, it would seem that there may even be some danger that the ventilation of the sewer by the stand-pipes in the streets may force the traps.

One is rather surprised to learn that the main outfall sewer is designed with a capacity of 90 000 000 liters per day, the present sewage being estimated as not more than 18 000 000 liters, and the far future being thought to require only 40 000 000 liters. Why this excessive size? Possibly the surplus water which it is to carry is to be discharged into the sewers from the water supply system direct, and is intended for irrigating the land at the disposal area, when the sewage is insufficient for this purpose. The author states that all surface water is strictly excluded.

The method of sewage disposal gives rise to several questions. It is proposed to use an extensive area for growing crops, which are to be irrigated with sewage. The paper states that the underlying strata at Monterrey contain numerous caverns, and the first question is: What will be the effect on the water supply of other towns lower down the valley? The writer recollects a serious outbreak of typhoid fever in Bluefield, W. Va., caused by the pollution of the water in similar strata finding its way through unknown underground caverns and channels to the city's water supply.

The next question is: What crops will be grown? It is a well-known fact that vegetables grown by the use of sewage as a fertilizer, are unsafe in a raw state for human consumption. This is well-known to European travelers in China and Japan, where the use of fecal matter as fertilizer renders the various water supplies (where not filtered and disinfected) and all green vegetables, unsafe, on account of typhoid germs. Moreover, crops not intended for human consumption, which are grown on lands irrigated by sewage bearing typhoid germs, etc., are unsafe for men to handle; even to store them may cause a dissemination of disease. It is evident, therefore, that the whole sewage flow should be in some manner disinfected at least, if not filtered, before it is used.

The method of sewage disposal and the use of merely settled septic sewage for irrigation seem to be open to objection. The disposal plant is not sufficiently effective to meet the present requirements of sanitary

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science; and the sludge-pit will be certain to breed a pest of flies, if it is not also an intolerable nuisance on account of foul smells. Monterrey would seem to be a proper place for the introduction of the Imhoff tank, with percolating filters, and a final settling tank, the effluent being disinfected before entering the latter tank. The flow might then be used safely for irrigation purposes for crops not to be eaten uncooked by man. The writer does not see how the method provided can possibly fulfill the object stated, to distribute on the land an effluent which will be "innocuous and clear," or how any consequential degree of purification can be obtained in the tanks provided.

While there are described in this paper many things to find fault with, there are also many things to commend. The water supply system, with its reservoirs, etc., seems to be admirable; and the methods of construction by which the expense for forms was reduced is very interesting. The parking and ornamentation of the grounds over the reservoir roofs cannot fail to benefit the people and popularize the work.

Mr. Meyer.

RUDOLF MEYER, M. AM. SOC. C. E. (by letter).—The writer, as Engineer for the Government (guaranteeing the concessionaires a gross return of 10% per annum on the capital invested), and as inspector of the various works has had exceptional opportunities to become acquainted, not only with their construction, but also with events leading up to the granting of the final concession under which they were built and will be extended. In order to judge of the extent to which the different engineers, in their turn contributed toward the design of these works, the writer has thought it desirable to submit a complete statement of all matters relating to the inception, investigations, surveys, tests, etc., previous to the adoption of the present plans.

Data regarding former investigations, plans, and concessions which have since lapsed, have been obtained from the Government archives. These refer to periods prior to Mr. Conway's engagement, and anterior to the retaining of Mr. Schuyler by the concessionaires, and Mr. Binckley's connection with the scheme, and they are presented here as complementary to the information in the paper.

Samuel M. Gray, M. Am. Soc. C. E., acting in the interest of some American capitalists (who had been induced by Col. J. A. Robertson, of Monterrey, to look into the merits of a concession acquired by him, for building these works), being guided by the Government's proposition to supply the city with water by damming the floodwaters of the Santa Catarina River in the narrow gorge through which the stream emerges from the Sierras, some eight miles from the city, had several soundings made and reservoir sites surveyed in the first two box cañons up the river, and prepared and presented to the Government several alternative projects, besides the one mentioned by Mr. Schuyler. Several different dam sites were designated by Mr.

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Gray, whose investigations extended over some two years, and were finally abandoned after he had designed the general outlay for a complete network of water mains and sewers for the city, on account of the unwillingness of the Government at that time, about 1897, to grant any guaranties as to bonds or income to the concessionaire or his assigns. Mr. Gray did not favor the general scheme of storing flood-waters as a water supply, but strongly recommended to the attention of the Government the greater advantages of deriving the supply from subterranean flow in the river, by an infiltration gallery driven into the water-bearing gravels in the Santa Catarina Cañon (only a short distance above the place where Mr. Binckley afterward established his bore-holes across the river). He proposed to take advantage of the steep slope of the river at a turn in the cañon, and from the lower end drive a tunnel through a projecting rock spur, which tunnel, though starting well above the ordinary reach of floods, would terminate in water-bearing gravel, at a sufficient depth below the surface of the river-bed to intercept part of the underflow. Mr. Gray, through investigations made under his direction, by Nathaniel Turner, M. Am. Soc. C. E., had ascertained that there was an abundant subterranean flow, and work had actually been started on the proposed tunnel.

The results of Mr. Gray's investigations were put at the disposal of Messrs. Mackenzie, Mann & Co. by Mr. Robertson, at whose offices Mr. Binckley prepared the first plans submitted by him for the approval of the Government.

After Mr. Gray's investigations, Messrs. Mackin and Dillon (F. H. Dillon, Assoc. M. Am. Soc. C. E.), under contract with the Government, prepared the following plans: For a dam in the Santa Catarina Cañon; for a pipe line, similar to the one proposed by Mr. Gray, to a reservoir and settling basin on the left bank of the river (a short distance above where the provisional pumping station was established afterward by Mr. Binckley), but on the flat above the bluff skirting the river, practically at the same elevation as the present high-pressure reservoirs; for a complete network of water mains and sewers in the city, indicating the approximate direction in which the sewage would be disposed of, either by turning it into the river or by spreading it over suitable lands, the location of which was to be determined later; and also a complete set of specifications.

On these data bids were invited by publication, and inquiries were received from several parties. Finally, Messrs. Stocker and Walker, of Scranton, Pa., entered into negotiations with the Government, and the present concession was agreed upon and granted.

Messrs. Stocker and Walker engaged the late E. Sherman Gould, M. Am. Soc. C. E., to prepare a plan for a storage dam in the Santa Catarina Cañon, and submitted plans for water distribution and sewers

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in the city, slightly modifying the original plans of Messrs. Mackin and Dillon.

In the fall of 1905, the concession was acquired by Messrs. Mackenzie, Mann & Co., of Toronto, Canada, together with all plans, etc., presented by the original concessionaires. The new concessionaires stated that they would examine the whole situation again, for the purpose of presenting modified plans for works.

Mr. Schuyler, in the interest of the new owners, had paid one flying visit to Monterrey when Mr. Gray's projects were brought to his notice, and the writer had an opportunity to show him the tunnel which had been started. Mr. Schuyler left for Brazil and did not return until February, 1906, when he was accompanied by the Chief Engineer appointed by the concessionaires. Messrs. Schuyler and Binckley then prepared plans for the water distribution and sewer systems in the city and for a provisional water supply to be pumped at San Geronimo, some two miles up the river. The new plans for the city work followed closely the general disposition by Mr. Gray, the principal difference being that the main reservoirs for the permanent water supply were located to the south instead of to the west. This change was due to the results of an investigation, made during Mr. Schuyler's absence in Brazil, by Mr. F. S. Hyde, late Hydraulic Engineer of the Necaxa Water Power plant, who, accompanied by the writer, visited the whole water-shed of the Santa Catarina River in October, 1905, in search of suitable dam sites and prospects of power development. Mr. Hyde extended his studies to the Santiago Cañon, southeast of the city, recommending finally that the water be brought from that cañon, and that wells be dug in different points of the Santa Catarina River between San Geronimo and the entrance of the cañon, and tested by pumping, for the purpose of establishing levels and ascertaining the available amount of underflow, with a view of determining the location for an infiltration gallery high enough up the river to permit of a gravity delivery and under good pressure in the city.

In view of Mr. Hyde's report, and as the result of a visit to the Santiago Cañon, Mr. Schuyler decided to locate the reservoirs south of the town, intending to bring in water from the southeast, from springs in the Santiago Cañon, and also by infiltration from Santa Catarina, his and Mr. Binckley's scheme of water supply being for the same pressure throughout the city.

To supply water during construction, and partly meet the demands of the city, Mr. Binckley, on his arrival, decided to establish a provisional pumping station at the well in the river nearest to town, started by direction of Mr. Hyde at San Geronimo. This well was situated within the bed of inundation of high floods, on a low bank, at the foot of a conglomerate bluff some 20 ft. high, limiting a flat which was above the reach of any flood. It was on the same side of the river

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as the city, and there was plenty of good ground on the flat above for the establishment of a reservoir.

A slightly shorter pipe line was secured by crossing the river, building the reservoir (a substantial concrete-lined and vaulted-over structure) on the opposite bank, laying out the pipe line to follow that bank nearly to the city, and finally crossing back again; but the result has been that since the flood of August, 1909, in which the river crossings were destroyed, the reservoir remains isolated on the other side of the river from town, though intended to form part of the permanent works and act as a compensating reservoir for equalizing the pressure of the high-pressure system. Fortunately, the pumping station, the larger pumps, and the boilers, had been moved up the bank (after a rapid rise in the river on August 10th, 1909) to the new wells established by Mr. Conway on the line of the proposed prolongation of the infiltration gallery. The reservoir, however, is left to stand alone on the other side of the river, and its usefulness will not be restored until a new line is laid across the river, re-establishing its connection with the new pump line and the new and permanent pipe line to be laid along the north bank from the pumping station to the city. This will free Monterrey from the constant menace of a water famine. At present its two main water supplies may be cut off by unexpected floods like those of 1909 and 1910, as both supplies are carried across the river, and though only the cast-iron pipe connecting with the water supply from Estanzuela was carried away by the flood, the concrete conduit of the San Geronimo low-pressure supply was seriously threatened. Such risks are too great to be carried for any length of time; besides, a succession of dry years would cause such a reduction in the Estanzuela supply as to require an additional reserve in the way of pumping stations drawing on the under-flow of the river, such as already exists in San Geronimo.

Afterward, Messrs. Schuyler and Binckley submitted preliminary plans and profiles for the projected concrete gravity conduit from Estanzuela to the reservoir south of the city, and Mr. Binckley submitted excavation plans for two reservoirs, only one of which was built, and from designs by Mr. Conway.

Stephen E. Kieffer, M. Am. Soc. C. E., was intrusted by Mr. Binckley with the revision of the plans of the water distribution and sewers. The southern half was approved by the Government and executed according to his plans; the northern part was afterward revised by Mr. Conway and has been partly built.

The final maturing of the project of an infiltration gallery in San Geronimo as a low-pressure gravity supply, the division of the city into high- and low-pressure districts corresponding to the two supplies, with one reservoir, instead of two to the south of the city, and the other to the west at the Obispado, the entire details of both these gravity

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schemes, and of the whole sewage disposal scheme, as well as the modification introduced into the city work for the northern half, are unquestionably due to Mr. Conway, independently of the general views which may have been held on those points by other engineers.

In March, 1910, Mr. Conway left Monterrey, all the principal works being finished. Since that time Vicente Saucedo, Assoc. M. Am. Soc. C. E., has put in many additional water mains and sewers in the northern part of the city, and is finishing the *force majeure* work caused by the destruction wrought in the districts along the river banks by the extraordinary floods.

The writer, having had an opportunity to watch the earnest efforts of the several engineers connected with these works, in the course of their design and construction, resulting without doubt in being the first of their kind built in Mexico, has been induced to contribute this discussion in order to bring out clearly the share of each.

Mr. Pitkethly's apprehensions as to the adequacy of the system of ventilation adopted have not been realized, in part perhaps because the houses, though generally of only one story, have such high ceilings that the tops of their vent pipes are generally higher than the ventilating columns at the heads of the branch sewers.

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GEORGE ROBERT GRAHAM CONWAY, M. AM. SOC. C. E. (by letter).—The writer regrets that some features of the works described in this paper have failed to call forth the many useful criticisms which he expected, and his remarks, therefore, are limited to the few points which have been raised. He is particularly indebted to Messrs. Schuyler, Meyer, and Saucedo for adding supplementary information of value to the paper, but regrets that he cannot support Mr. Binckley in his claim that "the entire general design of the system, as well as the extensive hydrological studies and final selection of the sources of water supply, was completed in 1906," etc. On May 1st, 1907, when the writer assumed responsibility as Chief Engineer, he was unfortunately confronted with the fact that very little data and only a few preliminary and incomplete plans were available. His first duty was to report upon the final sources of supply, and the recommendations made in his report (dated July 12th), received Mr. (now Sir William) Mackenzie's approval during the same month. The final plans, upon which the approval of the State Government was definitely obtained, were prepared by the writer during the summer of 1907, were submitted to the Governor of the State, Gen. Bernard Reyes, on October 19th, and received his approval on December 12th, 1907. No works, with a long preliminary history, such as those at Monterrey, can rightly be said to be due to any one individual; many engineers contributed to the final result, and the writer willingly acknowledges his indebtedness to the able men, who, for ten years prior to the construction of the

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works, investigated the particular problems which were met—problems which were not only of an engineering and physical nature, but racial and financial. The responsibility of constructing the works in their present form, and leaving them practically complete, did, however, fall on the writer's shoulders.

Messrs. Pitkethly and Hammond have criticized the basis of the calculations upon which the sewer system was laid down. In considering this problem, it is necessary to remember that, in designing this system, there was practically no information upon which to base the calculations; and the writer believed that the wisest course was to anticipate a liberal growth, and provide a large margin of safety. In designing a sewer system in older and well-established communities, the engineer is generally able to compile considerable information regarding the probable sewage flow for which it is necessary to provide. In Monterrey this quantity was absolutely unknown. The writer's practice in other places has been to assume that about 8% of the total daily discharge of sewage will flow off in one hour; and, from many curves which he has plotted regarding sewage flow in British towns, this rate appears to him to be approximately correct. In Monterrey, however, the old Mexican traditions are rapidly changing, and the city is now becoming one of the most Americanized in Mexico; the old one-story houses will give way in time to buildings of several stories—a change, already noticeable, which has occurred during the past few years, particularly in the business portion of the city. Taking these facts into consideration, it is believed that it would be, not only bad engineering, but bad business, for a company whose concession lasts 99 years, to provide sewers as small as 6 in., as Mr. Hammond would recommend, and then be called upon, under the terms of the concession, to relay larger sewers at a future date, thus incurring further capital expenditure upon which no Government guaranty would apply, and no further revenue be obtained. In matters of this kind, not only the engineering, but the commercial, aspect of the question must be kept in view, and this point, the writer must frankly admit, he has always seriously considered.

The writer's experience with reference to the method of ventilating sewers by tall columns extends over many years, and he still maintains that no other system gives such satisfactory results. In this view he finds considerable support in a recent paper on "Salisbury Drainage," by Mr. W. J. E. Binnie,* written since the system at Monterrey was installed, in which the result of a series of experiments carried on during 1906-07 are given. At Salisbury, England, 68 ventilators, 6 in. in internal diameter, 30 ft. high, were connected to the main sewer by 6-in. stoneware pipes. They were placed about 540 ft. apart,

* *Minutes of Proceedings*, Inst. C. E., Vol. CLXXXI, p. 317.

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and, from careful anemometer readings, the following conclusions were reached:

"(1) That four ventilators all lying in the lower portion of the town acted sometimes as air-inlets and sometimes as air-outlets, and that the other sixty-four acted as air-outlets.

"(2) That the average velocity of the air escaping up these columns was 3.2 feet per second, representing the circulation of 3,600,000 cubic feet of air per diem, or sufficient to change the air in the sewers every 10 minutes.

"(3) That the average velocity of the current of air in the ventilating-column increases with the size of the sewer to which it is connected, averaging 2.4 feet per second with the 7-inch sewer, 3.6 feet per second with the 9-inch sewer, 3.7 feet per second with the 12-inch sewer, and 4.1 feet per second with the 15-inch sewer in these experiments.

"(4) That the draught in the column is very largely dependent on the wind, being at its minimum on a still day, and could therefore be readily increased by the use of a suitable cowl.

"(5) That the draught is very little affected by the sewer-gradients. It was expected that, in ventilating-columns placed in connection with the upper end of a sewer laid at a steep gradient, a strong draught would have been obtained. No direct connection, however, was traceable."

As the result of these experiments, Mr. Binnie rightly came to the conclusion that this system of ventilation was efficient.

Mr. Hammond anticipates that the house connection trap system at Monterrey will lead to bad results, but the writer has seen the system at work in many widely different cities with excellent results. He believes that it is in accord with the best practice of the most eminent sanitarians during the last 20 years, and has no apology to make for introducing that system in Monterrey.

Regarding Mr. Hammond's summary of the advantages of concrete pipes for sewer construction, the writer is in entire agreement, and would willingly have introduced them throughout the whole of the Monterrey system, but for the fact that it was an exceedingly difficult matter to obtain suitable sand for their manufacture during the early days of construction, and considerable delays would have arisen if a complete network of such pipes had been used. His later experience at Monterrey, when the sand difficulty had been solved, clearly showed that concrete pipe could be laid down at much less expense than fire clay.

Both Mr. Pitkethly and Mr. Hammond refer to the system of liquefying tanks used at Monterrey preparatory to turning the sewage on the irrigation lands, and both express doubts as to their efficiency. The writer is now separated from his library and notes by many thousands of miles, and cannot quote "chapter and verse" as accurately as he would like, in order to support his views that the system adopted

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was adequate for dealing with a system such as that at Monterrey. It must be pointed out that not only was it intended to prevent the sewage from becoming a nuisance, but that the sewage flow plus a large quantity of surplus water was intended to be used profitably for irrigation purposes. With that object, the Company—or rather its allied Company, the Monterrey Railway, Light, and Power Company—obtained the control of 2 246 acres of the very finest arable land, with almost perfect natural drainage conditions, so that this land could be utilized to create a profitable revenue from the use of the sewage. The outfall sewer was accordingly designed to carry sufficient water and sewage to irrigate about 2 500 acres of land, which area could be considerably extended if necessary at any future time.

Most authorities now agree that before turning sewage upon land, a preliminary treatment is required to remove as much as possible of the suspended matter, and then reduce the latter by subsidence in liquefying or septic tanks, so that the quantity remaining in the effluent is so small and finely divided that it may be readily decomposed and oxidized by bacterial action without risk of clogging the surface or interstices of the land upon which it may discharge.*

Mr. Pitkethly quotes Messrs. Watson and O'Shaughnessy as saying, in their evidence before the Royal Commission on Sewage Disposal, that not more than 10% of the solids are digested in septic tanks, but it must be remembered that in many other places evidence was given before the same Commission showing that from 25 to 30% was actually obtained.

Mr. J. D. Watson, in his paper, "Birmingham Sewage-Disposal Works,"† read in March, 1910, points out that:

"The much-maligned sewage-farm still may be allowed (where the conditions are favourable) to rank as one of the best methods of sewage-disposal. Diverse opinions may be held as to what are favourable conditions, particularly as conditions are sure to vary widely with locality; but it may be assumed that where there is 1 acre of suitable land per 100 persons, as in Berlin and several other important cities, the efficiently-worked sewage-farm, when judged solely by the standard of the effluent produced, is still in the front rank. Effluents from such a farm are remarkable for their paucity of micro-organisms, their low albuminoid ammonia, and their unvarying character."

Assuming that not more than 2 000 acres of the irrigated land at Monterrey were available for sewage purposes, this area would represent the sewage treatment of the present population of not more than 45 persons per acre, and on the basis of the design, that is, for a population of 200 000 persons, this represents not more than 100 persons per acre. In many sewage farms on the continent of Europe, the number

* See Raikes, "Sewage Disposal Works," pages 97–98.

† *Minutes of Proceedings*, Inst. C. E., Vol. CLXXXI, p. 259.

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treated per acre varies between 80 and 200 persons; for example, at Breslau it is 187, at Berlin 105, at Brunswick 88, and at Steglitz 185.

Regarding the crops to be grown on the land, very satisfactory results were obtained from growing Indian corn, and two excellent crops per annum were taken from an area of 500 acres during the period in which the writer was responsible for the works. It was also his intention to grow alfalfa, and turn a part of the land into a pecan grove, and, although he does not share the apprehensions of danger of either Mr. Pitkethly or Mr. Hammond as to growing root crops, he believes the growth of alfalfa, Indian corn, oats, barley, and pecan and fruit trees is eminently suitable for the land, which is a deep rich loam, from 4 to 8 ft. deep, overlying the "sillar" formation referred to in the paper. The writer has seen many sewage farms during the last 18 years, upon which root crops of excellent quality have been grown, and not the least suspicion has ever been raised regarding their use.

In reference to the adoption of the monolithic form for constructing the South Reservoir, the writer is so convinced as to its economy that had he to build this reservoir again, he would adopt the same method. Mr. Binckley, in drawing attention to the method of construction, has overlooked the fact that the cost of forms for a reservoir 30 ft. deep was a very serious item, and warranted the adoption of this new method, not only on account of economy but because of rapidity of construction; while, in the case of the Obispado Reservoir, which is very much shallower, simpler forms could be and were adopted.

Mr. Saucedo's remarks regarding the repetition of the extraordinary floods of August, 1909, in September, 1910, are particularly interesting, and show how abnormal conditions are in so dry a section of Mexico as the State of Nuevo León. These two floods, the writer believes, are among the most instructive in North America, particularly when one remembers that prior to 1909 the average rainfall during a period of 15 years, was less than 22 in. per annum.

TABLE 17.—COMPARISON OF VOLUME OF FLOODS, ETC.

River.	Drainage area, in square miles.	Maximum recorded flow, in cubic feet per second.	Cubic feet per second per square mile.	Annual amount of rainfall.
Santa Catarina, Monterrey, August 27th, 1907	544	235 000	432	22
Estanzuela, near Monterrey, August 28th, 1909	3.5	2 900	825	25
Tansa, India	52.5	35 000	666.7	101
Krishna, India	345	118 000	342.6	258
Coquitlam River, Vancouver, B. C.	100	12 000	120	147–189
Sweetwater, Cal	186	18 150	99	....
Delaware, Lambertville, N. J.	6 820	250 000	36.5	45
Colorado, Austin, Tex	37 000	123 000	3.3	24.5
Ohio, Cairo, Ill.	214 000	700 000	3.3	54.9

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Table 17, compiled by the writer, shows how very extreme the floods of 1909 were compared with those on other rivers, while those of 1910, referred to by Mr. Saucedo, although not so great, would appear to have reached a rate of flow of about 300 cu. ft. per sec. per sq. mile of the drainage area.

The writer agrees with Mr. Saucedo that in the semi-arid regions of Mexico and the Southern States, and also in India, the possibility of these abnormal floods is an important consideration in the design of hydraulic works.

MEMOIRS OF DECEASED MEMBERS

JAMES ARCHBALD, M. Am. Soc. C. E.*

DIED OCTOBER 4TH, 1910.

By the death of James Archbald, this Society loses one of its oldest and most highly esteemed members, and one who will be sadly missed at its annual reunions, at which he was a most constant attendant.

James Archbald was born at Sand Lake, N. Y., the temporary residence of his parents, on February 13th, 1838. He was a son of James and Augusta T. Archbald, and was of mixed Scotch and New England ancestry. His father was born on the Little Cumbrae Isle, off the coast of Ayrshire, Scotland, being descended on his mother's side from the Reverend Robert Wodrow, a prominent Presbyterian divine and writer; and his mother was the daughter of Major Thomas Frothingham, of the well-known family of that name of Charlestown, Mass.

James Archbald, Senior, was connected with the Delaware and Hudson Canal Company for nearly thirty years, its mining operations at Carbondale, Pa., being under his superintendence from a very early date. He was afterward Chief Engineer of the Delaware, Lackawanna and Western Railroad for some fourteen years, being stationed at Scranton, Pa.

Following in the footsteps of his father, Mr. Archbald took up the Engineering Profession. He prepared for college in private schools at Carbondale, Pa., and at Manlius, N. Y. After some little experience in the field, he entered Union College, taking the Engineering course, then under the brilliant direction of Professor Gillespie, and was graduated with high honors in the Class of 1860. In the meantime, in 1857, his family had moved to Scranton, Pa., and there, after his graduation, Mr. Archbald became associated as Civil Engineer with the Delaware, Lackawanna and Western Railroad in the capacity of Assistant to his father. On his father's death, in 1870, he was advanced to the Chief Engineership, and remained with the company in that position until 1899, giving it nearly forty years of service.

The Archbalds—father and son—were thus identified with the development of the two great coal companies of the Northern Anthracite Region, The Delaware and Hudson, and The Delaware, Lackawanna and Western, their joint association with these companies extending over a period of more than seventy years. Among the engineering achievements in which the older Archbald participated was the change of the Delaware and Hudson, in the middle Fifties,

* Memoir prepared by C. C. Rose and William M. Marple, Members, Am. Soc. C. E.

to a gravity road between Carbondale and Honesdale, previous to which time the cars were drawn back and forth, from one plane to the other, on a dead level, by horses; and its extension as a locomotive road from Carbondale in the direction of Scranton. The younger man was engaged on the Delaware, Lackawanna and Western Railroad, in the completion of the Van Ness Gap Tunnel at Oxford, N. J.; the building of the Bergen Tunnel at Hoboken, and the approaches to it across the Hackensack Meadows; and the extension of the railroad from Great Bend, Pa., its previous terminus, first to Binghamton, and then to Utica and Buffalo, with the arrangement of the terminals in the latter city. The construction of the Bergen Tunnel, with its approaches, and the Buffalo extension, were under Mr. Archbald's immediate direction as Chief Engineer, and may be regarded as monuments to his superior skill and energy.

In August, 1862, the darkest period of the Civil War, Mr. Archbald enlisted, and was made Captain of Company I of the One Hundred and Thirty-second Pennsylvania Volunteers, which was recruited from Delaware, Lackawanna and Western Railroad men; and with his company, a month later, he took part in the battle of Antietam, being under fire at one of the most exposed and bloodiest points in that memorable battle. He served until January, 1863, when he applied for and obtained a discharge, being threatened with permanent deafness due to exposure.

In 1883, without severing his relation with the Delaware, Lackawanna and Western Railroad, but being relieved of some of his more active duties, Mr. Archbald became interested in the Barber Asphalt Paving Company, and took charge of its paving work in different sections of the country—Buffalo, New Orleans, St. Louis, Omaha, and Portland. Later, however, he severed this connection and resumed his work with the Delaware, Lackawanna and Western Railroad, continuing with that Company until 1899.

After his retirement, Mr. Archbald gradually gave up his professional activities, but was called at times to important undertakings. In the winter of 1900 he had charge of a survey to connect the various independent collieries in the Lackawanna and Wyoming coal regions, with the Erie and Wyoming Railroad, looking to the building of a new anthracite coal road to tidewater. After the abandonment of that project he laid out a line of railroad across the Allegheny Mountains, in West Virginia, for the Cherry River Lumber Company, to connect with the Chesapeake and Ohio Railroad. He also, in 1902, made surveys for the extension of the West Virginia Central Railroad to tidewater, a project made unnecessary by the purchase of the Western Maryland. His last professional work was as Chief Engineer of the Mississippi Central Railroad, laying out and superintending the construction of its road across the State of Mississippi, from

Natchez to Hattiesburg, with a projected extension to the Gulf at Scranton, Miss., with which he was occupied from 1905 to 1907, retiring finally, at the conclusion of this work, with powers unimpaired, at the age of seventy.

Mr. Archbald was a Member of the Institute of Mining Engineers, and was one of the Founders and the first President of the Scranton Engineers' Club. He was a Director of the Third National Bank of Scranton, from its organization in 1872; a Director of the Scranton Gas and Water Company, a Trustee and Vice-President of the Albright Memorial Library, and a Director of the Pennsylvania Oral School for the instruction of deaf children. He was also, for a number of years, a Director of the Scranton Savings Bank.

On January 25th, 1865, he was married to Miss Maria H. Albright, a daughter of the late Joseph J. Albright, General Sales Agent for the Delaware and Hudson Company, and his widow and six children, Col. James Archbald, of Pottsville, Pa.; Joseph A. Archbald, of Buffalo, N. Y.; Mrs. John C. Kerr, of Englewood, N. J.; Rev. Thomas F. Archbald, Mrs. John H. Brooks, and Miss Ruth S. Archbald, of Scranton, survive him. He is also survived by his youngest brother, United States Judge, Hon. Robert Wodrow Archbald.

In August, 1910, Mr. and Mrs. Archbald went to Europe for a three months' tour. It was purely a pleasure trip, and was to extend through Switzerland, Austria, and Italy. Mr. Archbald was apparently in the best of health and spirits; but it was found that his heart was affected by the high altitudes of the Tyrol. He went to Vienna, for medical examination, and was declared to have no organic infirmity, but was advised not to exert himself unnecessarily. Journeying on to Venice, he seemed to improve, and spent a week in that city, but just as he was leaving, on October 4th, he was stricken at the station, and died the same evening in a hospital. Thus passed away one who loved and deserved well of the Profession, and who was loved and respected by all who knew him.

Mr. Archbald was genial, unassuming, of simple presence, of sterling integrity, and a hater of shams. He was possessed of the highest engineering ability, especially in the field, which was his school rather than the office. It is not necessary to dwell on his characteristics to those who had the pleasure of his acquaintance; but, for those who had not, let it be recorded, that no better friend, no worthier citizen, no more active and few more able engineers, could be found.

Mr. Archbald was elected a Member of the American Society of Civil Engineers on May 15th, 1872.

JAMES HENRY COVODE, M. Am. Soc. C. E.*

DIED SEPTEMBER 9TH, 1909.

James Henry Covode was born in Westmoreland County, Pennsylvania, on October 18th, 1858. He was a son of the Honorable John Covode, a Representative in Congress for twenty-six years, covering the period of the War of the Rebellion, during which he earned the title of "Honest John Covode" as a Member of the War Committee. He subsequently served as a Member of the Committee to investigate the charges against President Buchanan. Mr. Covode's mother was Margaret Peale, a descendant of Rembrandt Peale, the famous artist.

After preparing at the Chester Military Academy, he was graduated with the degree of Civil Engineer from the Rensselaer Polytechnic Institute in 1882. After graduation, he went to the Pennsylvania Railroad in charge of construction on the Sea Isle City Branch until the autumn of 1883, when he was put in charge of the piers, wharves, and freight-house construction at Canton, Baltimore, Md., until February, 1884. He was then tranferred to the Maintenance-of-Way Department, and subsequently was attached, for one year, to the General Superintendent's office as Assistant Engineer in charge of surveys in the field. In 1886, he was transferred to Pittsburg, Pa., in charge of the reconstruction of the Pittsburg Yard, in connection with the introduction of interlocking switches and signals.

In February, 1888, Mr. Covode left the service of the Pennsylvania Railroad and became Chief of Party on the location of the projected Nicaragua Canal, under General Menocal, on which work he remained for nearly two years. In 1889, he was invited to become Consulting Engineer for Don Eduardo Casey, a wealthy citizen of the Argentine, who was engaged in large undertakings in that Republic. Mr. Covode retained this position until the failure of Baring Brothers put a temporary end to development plans in the Argentine Republic.

Returning to the United States, Mr. Covode became interested in contracts for building a portion of the Midvale Branch of the Pennsylvania Railroad. In 1893, he associated himself with the California Alcatraz Asphalt interests, and introduced this pavement into a number of Eastern cities. He continued to be interested in the Asphalt Company until the formation of the Trust in 1899.

After 1899 Mr. Covode became engaged in mining operations in California, Nevada, and Mexico, in which he continued until his death, which was caused by over-exertion in high altitudes in Bolivia, South America. He had gone to Bolivia, in the interest of a New York syndicate, to look over the mining developments in the Andes, travel-

* Memoir prepared by A. H. Renshaw, M. Am. Soc. C. E.

ing into altitudes of 20 000 ft., and on his return to La Paz, he died suddenly from the effect of the undue strain on his heart.

In February, 1897, he married Miss Louise Bournonville Moulder, of San Francisco, Cal., who alone survives him.

Mr. Covode was a worthy son of a worthy father, and deserved the honorable title of "Honest" in the same sense that his father had earned it in war times. He also had a very lovable character. His self-sacrificing loyalty to friends and to those who trusted themselves or their interests to him, was the most marked of his many sterling qualities, leading him too frequently to subordinate his interests and welfare to those of others.

He was an able Engineer, and his varied experience would have fitted him for many years of usefulness in the Profession, but for his untimely death.

Mr. Covode was elected a Member of the American Society of Civil Engineers on April 2d, 1890. He was also a member of the San Francisco Association of Members of the American Society of Civil Engineers, of the Engineers and Delta Phi Clubs of New York City, and of the English Club of Monte Video, Argentine Republic.

HENRY HARDING, M. Am. Soc. C. E.*

DIED OCTOBER 23D, 1910.

Henry Harding was born on December 10th, 1837, at Hartland, Vt., where his father, Dr. John Harding, was a physician for many years.

He studied engineering under Mr. Job Atkins, a mining engineer of Richmond, Va., during 1859-60, and was afterward engaged on the construction of the Hudson River Railroad.

From 1865 to 1870, Mr. Harding was employed, under General Grenville M. Dodge, on the survey and construction of the Union Pacific Railway. He was also employed on the Adirondack, Housatonic, and Naugatuck Railroads, in charge of construction and in various other capacities.

From 1871 to 1895, he was engaged at intervals by the United States Corps of Engineers in charge of river and harbor improvements and other work, and was wont to recall with especial pride the construction of the fortifications of Fort Adams, at Newport, R. I., in 1871-73.

While in the employ of the Government, Mr. Harding contracted malaria, and, in 1895, he retired to his home at Hartland Four Corners, Vt., where he continued to live until his death.

Mr. Harding was a man of wide acquaintance and high reputation in his Profession, to which he was devoted, and, although living in a secluded country village, he kept well abreast of all the improved methods and was familiar with all new instruments used in engineering work. At the time of his death, he was engaged as Engineer in charge of the construction of the new sewerage system of Windsor, Vt.

Mr. Harding was the embodiment of painstaking accuracy and scrupulous honor, and any work done under his superintendence was honestly constructed and fully served its purpose. He was of a genial and courteous manner, modest, kind-hearted, and drily humorous, an agreeable and interesting social companion. He never married, and is survived by several nephews and nieces.

Mr. Harding was elected a Member of the American Society of Civil Engineers on May 7th, 1873.

* Memoir prepared by the Secretary from information on file at the House of the Society.

CHARLES CYRUS KING, M. Am. Soc. C. E.*

DIED JANUARY 13TH, 1911.

Charles Cyrus King was born at Bellmont, Franklin County, N. Y., on October 2d, 1845. He entered Cornell University in 1871 and was graduated in the course of Architecture in 1875. Like other self-reliant and resourceful men of his day, he worked his way through the University, and, in spite of this handicap, was graduated with high attainments as an Architect. Among Cornellians he will be most familiarly remembered as a member of Cornell's first 'Varsity crew in the Rowing Association of American Colleges at Springfield, Mass., in 1873, and also in the regattas of 1874 and 1875, at Saratoga.

Mr. King's first work after graduation was with the Sailors Snug Harbor, of Staten Island, and the noteworthy buildings of classic architecture which were erected during his connection with that institution stand as lasting monuments to his memory and attainments.

In 1886 he became one of the original incorporators of the C. W. Hunt Company, of Staten Island, and since that time he has been a Director and also Chief Engineer of the Company. Although an Architect by profession, his profound and deliberate mind made him an Engineer of unusual ability, whose judgment was highly valued by his Company, and he was in the midst of his usefulness and mental vigor when he died.

Mr. King was modest and retiring, to a fault, but his close friends and those who had the privilege of meeting him at home will always remember his charm of character. He designed and built his artistic home, and enjoyed it for eighteen years with his devoted wife who survives him.

His funeral, held at the family residence, West New Brighton, Staten Island, at 2.30 P. M., on Sunday, January 15th, 1911, was attended by old comrades and business associates who took this last opportunity of expressing as tenderly as possible their love and admiration for a departed friend.

Mr. King was elected a Member of the American Society of Civil Engineers on September 2d, 1891. He was also a Member of the American Society of Mechanical Engineers.

* Memoir prepared by John N. Ostrom, M. Am. Soc. C. E.

EVELYN PIERREPONT ROBERTS, M. Am. Soc. C. E.*

DIED DECEMBER 30TH, 1910.

Evelyn Pierrepont Roberts was born at Fort Leavenworth on Christmas Day, 1848, when what is now the State of Kansas was the Indian Territory and Fort Leavenworth one of the extreme outposts of the civilized frontier of the United States. His father was General Benjamin Stone Roberts, U. S. A., and his mother, Elizabeth Pierrepont Sperry. On both sides he was descended from distinguished ancestry. The first Roberts came from England about 1620, and his descendants took part in the Revolution and various Indian Wars. On his mother's side the line runs back to Evelyn Pierrepont, Duke of Kingston, whose son, James Pierrepont, was the first clergyman to settle in New Haven, Conn., and became one of the founders of Yale College.

In 1870 Mr. Roberts was graduated from the Sheffield Scientific School of Yale, and went West. He found employment on the staffs of the Northern Pacific Railroad west of the Rocky Mountains, the Canadian Pacific Railway in British Columbia, and the Spring Valley Water-Works, of San Francisco, Cal.

Returning East he was employed on the Croton Aqueduct, and subsequently acquiring some valuable granite properties, he took up masonry contracting as well as maintaining practice as a Consulting Engineer. He constructed the foundation for the elevated portion of the New York Subway and the great granite arches of the Cathedral of St. John the Divine, in New York City, which latter he always considered his greatest achievement.

Notwithstanding his many business interests, Mr. Roberts found time for altruistic work, especially the obtaining of employment for those unfortunates who had served prison sentences and who appeared to be anxious to begin life anew and earn an honest livelihood. Of this work he spoke only to his intimates, and, consequently, the great good and charity he did was known to few, in many cases only to the recipients.

Mr. Roberts was married July 5th, 1903, to Helen Frances Caleb, who, with one son, survives him.

He was a member of the Century, Yale, and Church Clubs, the National Geographic Society, the Military Order of the Loyal Legion, Sons of the Revolution, Fraternity of Delta Psi, and many other similar organizations. He was also a Director of the Danville and Mt. Morris Railroad; President and General Manager of the Mohegan Granite Company; and Director of the Jerry McAuley Cremorne Mission.

Mr. Roberts was elected a Member of the American Society of Civil Engineers on May 7th, 1884.

* Memoir prepared by William Barclay Parsons, M. Am. Soc. C. E.

SAMUEL McMATH ROWE, M. Am. Soc. C. E.*

DIED MAY 22D, 1910.

Samuel McMath Rowe was born in Dearborn County, Indiana, on February 8th, 1831. He went to La Salle County, Illinois, about 1842, and lived at the place where the Town of Sheridan is now located. Prior to the Civil War he was a Surveyor in and about the same locality.

In 1868 he located the line of what was then the Ottawa, Oswego, and Fox River Valley Railroad, and in 1869 and 1870 was a member of the firm of Rowe and Jackson which was engaged in the work of constructing that line.

In 1872 Mr. Rowe became associated with Dr. J. R. Zearing in the firm of Rowe and Zearing, which was engaged in the construction of the Texas and Pacific Railway, from Dallas, Tex., eastward about 75 miles to Longview.

In 1874 this firm was awarded the contract for the construction of a railroad bridge across Trinity River, for the Texas and Pacific Railway Company, at Dallas, Tex., and also to extend the track 10 miles west thereof. In the summer of 1874 the firm moved to Sherman, Tex., and commenced to build the Trans-Continental Line of the Texas and Pacific Railway, laying it to a point about 80 miles east of Sherman. Moving to Texarkana, they continued the line westward, connecting with the part they had already built.

In 1875, Messrs. Rowe and Zearing were employed on the construction of the Orleans and Pacific Railroad.

Somewhat later, or about 1878, Mr. Rowe was engaged by the Santa Fé Road, in connection with track-laying, etc., near Florence, Kans. In the latter part of 1878, he was retained as Engineer in Charge of Water Service on the New Mexico Extension of the Santa Fé Road from La Junta south, in which position he remained until about 1880 or 1881.

In 1882 Mr. Rowe was appointed Resident Engineer of that railroad, with headquarters at Las Vegas, N. Mex., and while acting in this capacity in 1885 he was put in charge of the construction and operation of the timber preserving plant at that place. This was the first important plant of this kind in the United States.

Early in 1887, he was appointed Chief Engineer of the Atlantic and Pacific Railroad, and while holding this position, the "Red Rock" Cantilever Bridge across the Colorado River at The Needles, California, was built under his supervision.

* Memoir prepared by J. A. L. Waddell and A. A. Robinson, Members, Am. Soc. C. E.

In 1891 Mr. Rowe moved to Chicago and organized the firm of Rowe and Rowe, Consulting Engineers, the firm consisting of himself and his son, the late Robert D. Rowe, M. Am. Soc. C. E.

From 1891 until the time of his death, Mr. Rowe was engaged in work connected with the preservation of timber; and his "Handbook of Timber Preservation" is the result of some twenty-five years of careful and exhaustive study and practice. He labored to perfect the methods and appliances of the process, studying many principles connected with the operation of timber preserving. His business was to design and install timber preserving plants, making the plans and specifications, supervising the construction, and inspecting the work. Twenty-seven plants have been built, for which he either furnished plans and specifications or had supervision of the installation, and in most cases both. His work in this line for the most part was done for the various railroad companies of the United States and Mexico. He was also employed by the United States Government in the capacity of Expert in the Forestry Service, devoting a part of his time to the work during 1905, 1906, and 1907.

He was associated with J. A. L. Waddell, M. Am. Soc. C. E., during the construction of the South Halsted Street Lift Bridge over the South Branch of the Chicago River, which was completed about 1894, and in the preliminary work of the Northwestern Elevated and the Union Loop Elevated Railroads, of Chicago.

Mr. Rowe made a careful study of the subway question, and did considerable work in connection with the subway and harbor enterprises in Chicago. Later, he became a Director and Officer of the Chicago Subway Arcade and Traction Company, and was connected with and active in this company up to the time of his death; in fact, he attended a meeting of the company only a day or two before his final illness, which lasted about ten days.

Until the time of his death, Mr. Rowe was an exceedingly active man, and took part in many business affairs. He was an actual witness of the wonderful growth of the City of Chicago from a town of a few thousand inhabitants to a metropolis of about two and one-half million people; and he always took an active interest in, and had a thorough understanding of, the civic problems which confronted that city.

Mr. Rowe had many warm friends in the Engineering Profession, and also outside of it, who appreciated him for his sterling honesty and genial kindliness. He was a good citizen, a devoted husband and father, and a thorough and painstaking engineer.

He died of pneumonia on May 22d, 1910, at the advanced age of seventy-nine.

Mr. Rowe was elected a Member of the American Society of Civil Engineers on September 2d, 1885.

JOHN WRIGHT SEAVER, M. Am. Soc. C. E.*

DIED JANUARY 14TH, 1911.

John Wright Seaver, was born in Madison, Wis., on January 8th, 1855. He was descended from pure New England Revolutionary stock, the first Seaver coming to America shortly after the *Mayflower* Pilgrims. While very young, his parents moved to Buffalo, N. Y., where his father died, and where he received a public school education. At the age of thirteen, he left school to learn the machinist's trade. He entered the machine shop of the Shepard Iron Works, where he spent two years, and was then transferred to the drafting-room. His technical education was obtained at this time under the greatest difficulties by attending night school, which was three miles from his home, and to which he walked after working hard all day. He read such trade journals and engineering books as he could secure, and one of his treasured possessions was a copy of Haswell's "Engineers' and Mechanics' Pocket-Book," given him by his mother when he was fourteen.

At the age of eighteen, after being with the Shepard Iron Works for four years, Mr. Seaver entered the machine shop of the Howard Iron Works, and at twenty he was employed by the Buffalo Car Company as Assistant Superintendent in charge of about 1 000 men. He left this Company to become a member of the firm of Seaver and Kellogg, and at this time designed and built the first steel cars in the United States. These cars were not commercially successful, as they were too far ahead of their time.

After spending one and one-half years in this business, he became Assistant Engineer of the Kellogg Bridge Works. He made structural iron a specialty, and began to attract outside attention as an Engineer.

In 1880 Mr. Seaver moved to Pittsburg, Pa., and became Chief Engineer of the Iron City Bridge Works, for which firm he designed and built a number of notable bridges and other steel structures. In 1884 he became the Chief Engineer for the Riter-Conley Manufacturing Company, and in this capacity his reputation became world-wide. He designed and built blast furnaces, steel works, oil refineries, gasometers, buildings, bridges, and other steel constructions. He was instrumental in building up this concern to be one of the greatest of its kind in the world.

In 1896 Mr. Seaver, with S. T. and C. H. Wellman, formed the Wellman-Seaver Engineering Company, which finally became the Wellman-Seaver-Morgan Company. While with this Company he was Vice-President and Chairman of the Board, and a Director until his death.

* Memoir prepared by J. E. A. Moore, M. Am. Soc. C. E.

After being with this Company for ten years, Mr. Seaver became associated with J. E. A. Moore, M. Am. Soc. C. E., as Consulting and Contracting Engineers, with offices in Cleveland, Ohio. He continued in this work until his death.

Mr. Seaver's engineering experience was most varied, including the civil, mechanical, marine and mining branches of the profession. While in Buffalo he designed and built many large marine engines, the principal of which was that for the steamer *Great Western*, which was a remarkable vessel at that time. He designed and built the first steel head frame, and the first gantry crane used in America, and also, as previously stated, the first steel cars. He was an authority on structural steel construction of all kinds, as well as material handling, steel and iron manufacturing, and coke-oven machinery, and compiled the first standard steel railroad bridge specification, which was adopted by some of the large railroad companies.

The principal traits in Mr. Seaver's character were his resourcefulness and perseverance, and it can be said of him that he never gave up. An instance of his resourcefulness was displayed in Buffalo when it was discovered that, after the hull of a large vessel was ready for launching, the water was too low in the slip to float it; in order to overcome this, he tied several tugs across the mouth of the slip, and by working their propellers, the water was raised sufficiently to float the vessel, and she was launched successfully. His genial, sunny disposition made for him many close, warm friends, both in this country and abroad, and he was beloved by all who knew him. His liberality was his worst fault.

Mr Seaver died suddenly of apoplexy at his residence in Cleveland, Ohio, on January 14th, 1911, and is survived by his wife and four children, an aged mother, and two sisters.

Mr. Seaver was elected a Member of the American Society of Civil Engineers on November 6th, 1901. He was also a Member of the American Society of Mechanical Engineers, the Cleveland Engineering Society, and many other business and social organizations.

EDWIN MERRITT HOLMES, Assoc. M. Am. Soc. C. E.*

DIED FEBRUARY 11TH, 1911.

Edwin Merritt Holmes was born at Colorado Springs, Colo., on June 20th, 1878. He received his education at the 104th Street Public School, New York City; the Mattoon High School, at Mattoon, Ill.; the College of the City of New York, and Cornell University.

From 1898 to 1901, Mr. Holmes was employed, in the United States, on timber boundary surveys and in the construction of tram and narrow-gauge logging roads. He also had charge of the landscape gardening for a summer hotel, including an artificial lake, pavilions, etc., as well as the reconstruction of a dam for a gravity water supply.

From June, 1901, to May, 1902, he was with the Engineer Department of the Military Government of Cuba, at Santiago, as Rodman, Leveler, and Transitman on city improvements. He was also employed as Street Inspector in charge of repairs to all city property and the harbor dredge. During May and June, 1902, he was connected with the Department of Public Works of the Cuban Government, as Assistant Engineer and Inspector in charge of the construction of macadam roads and a concrete bridge.

Although a Civil Engineer by profession, Mr. Holmes turned his attention to mining, and in June, 1902, entered the employ of the Spanish-American Iron Company, at Daiquiri, Cuba, as Assistant Engineer in charge of designing and constructing appliances for handling the product of the mines, of opening new deposits of iron ore for the extraction of sample cargoes, etc. In August, 1906, he was made Assistant General Superintendent of the Company, in direct charge of all engineering work, together with other duties connected with the operation of the mines.

On February 1st, 1909, Mr. Holmes was appointed General Superintendent of the Juragua Iron Company, and took charge of the operation of its mines at Firmeza, Cuba, which position he filled with conspicuous ability until his death.

Mr. Holmes was not married. He is survived by his father, Rev. Benjamin F. Holmes, of Clairmont, Va., two brothers, Mr. Robert L. Holmes, of San Juan, Porto Rico, and Mr. F. C. Holmes, of Firmeza, Cuba, and one sister, Mrs. Paul English, of Muskogee, Okla.

Mr. Holmes was elected a Junior of the American Society of Civil Engineers on March 31st, 1903, and an Associate Member on January 2d, 1907. He was also a Member of the American Institute of Mining Engineers and of the American Society of Engineering Contractors.

*Memoir prepared by DeB. Whitaker, Esq., Vice-President and General Manager, Juragua Iron Company, Santiago de Cuba, Cuba.

ARTHUR KEDDIE MACFARLANE, Jun. Am. Soc. C. E.*

DIED NOVEMBER 1ST, 1910.

Arthur Keddie Macfarlane was born at Beckwith, Cal., on July 19th, 1887. His parents were Donald and Kate J. Leggett Macfarlane. He was named for Arthur W. Keddie, the first Chief Engineer of the Western Pacific, who is sometimes spoken of as the "Father of the Beckwith Pass and the North Fork Transcontinental Railroad Route." It seems to have been a coincidence that the youth thus named should have shown an interest in the Engineering Profession. His early life was spent at Beckwith, and a later period at Oroville, where he was graduated from the Oroville Union High School in 1905. In 1909 he received the degree of Bachelor of Science from the College of Civil Engineering, University of California.

Like many Western students, he spent some time in practical work before and during his college period. As early as 1903 he was with the location survey party of the Western Pacific. In succeeding years, for three different summer seasons, he held various positions in surveying parties working along the Feather River Cañon and across the old Salt Lake Desert.

On his graduation from the University, in May, 1909, Mr. Macfarlane accepted a position with the Benicia Iron Works, at Benicia, Cal. His ability was promptly recognized by this company, which sincerely mourns his loss and has given no uncertain testimony as to his faithful and efficient service. In his unfortunately short career he distinctly showed ability to work with other men to gain their respect and confidence, whether they were his superiors or his subordinates. His employers state that he was admired and respected by everybody connected with the Benicia Iron Works. This quality certainly would have helped him to speedy success.

For the Benicia Iron Works he designed a series of saw-tooth roof mill buildings of steel frame with concrete covering on metal lath; later, he had responsible charge of their construction, also of the installation of machinery. At the time of his death he had about completed plans for a system of handling work quickly and efficiently in the shops and yards. He felt his responsibilities; was always on hand, and anxious to see things go ahead. At times he had difficulty in getting efficient labor. This influenced him to compete with his men to spur them on and interest them in the construction. It was this zeal, in one sense, that may account for his accidental death, for it was during the performance of his duties as Superintendent of the works that the accident occurred. A guy wire of a hoist had become entangled.

* Memoir prepared by C. Derleth, Jr., M. Am. Soc. C. E.

and all his men being otherwise employed, Mr. Macfarlane attempted to free the wire himself. It loosened with a jerk sufficient to throw it upon a live wire of the Bay Cities Power Line which ran near a wall of the building. A current of 1 200 volts passed through his body.

The young engineer can afford to learn lessons from this man. In the field and shop it is always necessary to exercise care. On the other hand, he must be prompt and ready to meet danger, for no engineer can be successful who is equipped with theory and office room experience alone. He must learn to understand his workmen. He must appreciate the qualities of the materials he uses in construction. He must understand processes of manufacture and of machine installation. Such things he can study best in the field, in the trench, and in the workshop.

At the University of California Mr. Macfarlane made an enviable reputation as a student, but particularly as a man. He was an officer of the Student Civil Engineering Association, and in his sophomore year was President of his class. He received other marks of distinction from his fellow students. These indicate the temper of the man. He was high-minded, straightforward, and honorable. He took a keen interest in his University, and remembered it after he left his Alma Mater. Unlike some engineering students, he was a student of literature and broadly read. For several terms he was President of the Calimedico Club, one of the student organizations which at California represent the Eastern Dormitory Institutions.

Mr. Macfarlane was elected a Junior of the American Society of Civil Engineers on October 5th, 1909.

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OF THE

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